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Faculty of Science

Study programme: Geology
Branch of study: Geology

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SCF in Lower Palaeozoic sediments of the Barrandian area

SCF ve spodním paleozoiku barrandienské oblasti

Diploma thesis

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Prague, 2020

Statement:
I hereby state that I have completed this thesis by myself and that I have properly cited all literature and other information sources I have used. Neither this thesis nor its parts have been submitted to achieve any other academic title(s).

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V Praze, 14.08.2020

Podpis

Acknowledgment

First and foremost, I would like to express my sincere gratitude to Prof. RNDr. Oldřich Fatka, CSc., Dr. Tom Harvey and Mgr. Jakub Vodička. All three have been enormously helpful, patient and supportive, have provided me with great opportunities to learn about various aspects of palaeontology and have patiently discussed numerous topics related to this thesis with me, as well as provided me with beneficial comments on the research and the text of the thesis.

I thank to Mgr. Petra Tonarová, PhD. for help with determination of some of the scolecodonts figured in this thesis. I would like to thank to Mgr. Viktor Goliáš, PhD. for execution of X–ray diffraction analysis.

Finally, I want to thank to my family, and especially to my wife, for their great support during my studies.

This research was supported by the Grant Agency of the Czech Republic (GACR), project no. 18-14575S.

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Abstract

In recent years, the term small carbonaceous fossils (SCFs) has been established to accomodate fragile organic–walled fossils of micro– to mesoscopic size that are usually extracted by means of the 'low–manipulation HF extraction' method. This method has so far only been utilized by several authors and no reports have been published on the usage of the method on samples from the Barrandian area.

To test the applicability of the method, samples from the Barrandian area were processed. The samples came from eleven localities representing six stratigraphic units (Paseky Shale, Jince Formation, Letná Formation, Kosov Formation, Daleje Shale and Roblín Member). All the units have been studied before by 'standard' methods of palynological processing.

Various previously unreported fossils are described, including wiwaxiid sclerites, putative chaetognath remains and acritarch clusters. Furthermore, it is discovered, that the 'low–manipulation HF extraction' can also be used for extraction of originally calcareous fossils.

The pilot study provides a further proof that the 'low–manipulation HF extraction' is a useful tool with the potential to significantly expand our knowledge of fossil assemblages.

Key words: Small carbonaceous fossils, Cambrian, Ordovician, Devonian, Barrandian area

Abstrakt

‚Small carbonaceous fossils' (SCFs) je pojem, který byl zaveden v posledních letech k popisu organických zkamenělin mikroskopických až mesoskopických rozměrů. SCFs jsou typicky získávány z horninových vzorků za užití metody „low–manipulation HF extraction". Tato metoda je zatím užívána pouze několika autory a nebyla nikdy aplikována ke studiu hornin pocházejících z barrandienské oblasti.

K otestování využitelnosti výše uvedené metody v rámci Barrandienu byly vybrány vzorky z jedenácti lokalit, zastupujících šest stratigrafických úrovní: pasecké břidlice, jinecké souvrství, letenské souvrství, kosovské souvrství, dalejské břidlice a roblínské vrstvy. Mikrofosilní záznam všech výše uvedených jednotek byl v minulosti studován za užití „standartních" metod palynologické macerace.

Aplikací metody „low–manipulation HF extraction" byly získány fosilie, které nebyly ze studovaných úrovní dříve popsány (např. sklerity rodu *Wiwaxia*, pravděpodobné zbytky jedinců kmene Chaetognatha či shluky akritarch). Dále bylo zjištěno, že pomocí této metody lze extrahovat také elementy původně vápnitého složení.

Tato pilotní studie potvrzuje potenciál metody „low–manipulation HF extraction" pro získávání nových dat o fosilních společenstvech.

Klíčová slova: Small carbonaceous fossils, kambrium, ordovik, devon, barrandienská oblast

1. Introduction

Fossil record is the main source of information on history of life; however, the record is inherently incomplete and generally biased – the easier an organism gets preserved, the more probable is its discovery. This phenomenon extends to the point where our knowledge about the presence of some groups in the past environments is near to non–existent, often only based on finds from a few stratigraphic levels or localities exhibiting exceptional preservation. A significant portion of the organisms is not preserved or recovered at all. Therefore, a variety of methodological approaches has been devised, which allow us to obtain more fossil material and evaluate it more precisely. A great example of such an approach are micropalaeontological methods, as microfossils are often very difficult to study without proper methodology and equipment. However, every methodological approach has its constraints. Our own methodologically induced biases can, therefore, restrict our knowledge of the fossil record.

In recent years, the small carbonaceous fossils (SCFs) have been recognised as an informal group of organic–walled fossils. SCFs represent various elements that are either too large or fragile to endure standard palynological methods and thus usually become casualties of inherent methodological biases. Consequently, a more gentle 'low–manipulation HF extraction' method is necessary for their recovery. Although new, the study of SCFs has brought numerous important discoveries and has opened various possibilities, including widespread research on a variety of biomineralizing and non–biomineralizing groups, some of which were previously unknown or restricted to the rare exceptionally preserved biotas.

The goal of this thesis is to test – for the first time – specialized methodology utilized for SCF extraction on pilot samples from selected levels of the lower Paleozoic of the Barrandian area (Czech Republic). The Barrandian area has been studied extensively for two centuries and belongs to the best examined areas in the world. Therefore, it is excellently suitable for testing of the method as there are numerous previous reports on fossil (and especially microfossil) record available for comparison.

2. Small Carbonaceous Fossils (SCFs)

2.1 Definition of Small Carbonaceous Fossils (SCFs)

The term small carbonaceous fossils (SCFs) embraces an informal category of organic–walled fossils of micro- to mesoscopic size. The most exact definition has been provided by Harvey & Pedder (2013, p. 278): „SCFs are organic–walled fossils that are too small to be identified on bedding surfaces, but larger and more delicate than those typically recovered by conventional palynological processing". It is worth noting that the understanding of the term 'small carbonaceous fossils' significantly varies among separate authors.

SCFs are typically recovered by the methods of 'low–manipulation HF extraction' utilized for dissolution of fine-grained siliciclastic rocks (see Butterfield & Harvey 2012); however, comparable fossils have also been extracted using not so delicate methods (e.g. Harvey & Pedder 2013, Smith *et al*. 2016). Furthermore, SCFs have also been extracted from diverse lithologies, including sandstones (e.g. Slater *et al*. 2018a) and even carbonates (Jarochowska *et al*. 2016).

As has been pointed out above, SCFs are an informal group. Therefore, SCFs do not represent a taxonomic unit of any sort. Among objects assigned to this group we may find various scalidophoran sclerites (e.g. Smith *et al*. 2015, Slater *et al*. 2018a), loriciferans (Harvey & Butterfield 2017), appendages and filtering apparatuses of crustaceans (e.g. Harvey & Butterfield 2008, Harvey & Pedder 2013), various arthropod cuticles (e.g. Butterfield 1990, Slater *et al*. 2018b) as well as sclerites of wiwaxiids (e.g. Harvey & Butterfield 2011, Palacios *et al*. 2014), radulae of molluscs (e.g. Butterfield 2008), parts of hyoliths (e.g. Butterfield & Nicholas 1996), or even exceptionally preserved cyanobacterial sheets (Slater *et al*. 2017). Organic–walled fossils preserved and recovered in similar way have been described from late Ediacaran through Carboniferous (e.g. Taugourdeau 1967, Bartram *et al*. 1987, Manning & Dunlop 1995, Moczydłowska *et al*. 2015) although often not classified as SCFs by the authors of the respective papers. The SCF research has so far been mainly focused on Cambrian rocks.

2.2 Significance of SCF research

Although the history of the SCF research is relatively short and there is only a limited number of papers focused on this problematic, it has already been demonstrated that SCFs show a significant potential to improve our knowledge of fossil associations.

Several groups of organisms (including some of those mentioned above) show a very limited fossil record (usually due to lack of biomineralization), and often are restricted to levels of exceptional preservation. Study of SCFs has uncovered previously hidden variety and diversity of some of these fossil groups (e.g. Butterfield 1994), sometimes even allowing description of new taxa (e.g. Harvey & Butterfield 2017, Slater *et al*. 2017). It also extends known stratigraphic ranges (e.g. Harvey & Pedder 2013) and palaeogeographic distribution (e.g. Palacios *et al*. 2014) of such groups.

The presence of SCFs has also been proven to be helpful for other areas of research, including stratigraphy (e.g. Slater & Willman 2019), palaeogeography (e.g. Smith *et al*. 2016, Slater & Willman 2019) and palaeoecology (e.g. Harvey & Butterfield 2008).

A more complex summary of the current state of SCF–related research has been provided by Kovář (2018), however, some new publications focusing on the topic have appeared since then (e.g. Slater & Willman 2019, Slater *et al*. 2020).

For the purposes of this thesis, pilot samples of siliciclastic rocks were chosen from six stratigraphic units (Fig. 1). The selected stratigraphic units are: the Paseky Shale Member (Holšiny–Hořice Formation) and the Jince Formation of the Příbram–Jince Basin and the Letná Formation, the Kosov Formation, the Daleje Shale Member (Daleje–Třebotov Formation) and the Roblín Member (Srbsko Formation) of the Prague Basin. The published information on the lithology, depositional environments and fossil record of the individual stratigraphic units is summarized in Chapter 3.

3. Geological setting

3.1 Teplá–Barrandian Unit

The Teplá–Barrandian Unit (Central Bohemian Region or Bohemicum of some authors) is a regional geological term describing sequences of Precambrian and early Paleozoic age in an area delimited by the Bohemian Quartz Load in the west, the Litoměřice Fault in the northwest, its contacts with the Central Bohemian Pluton and the Kutná Hora Region in the south to southeast and the Elbe Line and the Boskovice Furrow in the east (see definition of Bohemicum in Chlupáč & Štorch 1992).

The Teplá–Barrandian Unit contains mostly slightly metamorphosed Cadomian basement (comparable for example with northern parts of the Armorican Massif) composed of volcano–sedimentary units recently interpreted as tectonic melange of accretionary wedge (e.g. Hajná *et al*. 2011). The Cadomian basement is in several areas unconformably covered by volcano–sedimentary sequences of Cambrian to Devonian age. The Teplá–Barrandian Unit is currently considered to be either a former independent terrain (or even a microcontinent; e.g. Havlíček *et al*. 1994, Fatka & Mergl 2009) or a part of shelf of peri–Gondwana (e.g. Servais & Sintubin 2009, Žák & Sláma 2018) during major part of the early Paleozoic. The Teplá–Barrandian Unit shows distinct geophysical characteristics when compared with the surrounding units (summary in Ibrmajer *et al*. 1989), especially a positive gravitational anomaly, reflecting the basement composition of the region (Buday *et al*. 1967). The Teplá–Barrandian Unit also differs from the surrounding units in its mantle–lithosphere structure (e.g. Babuška & Plomerová 2013, Žák *et al*. 2014).

In the early Paleozoic of the Teplá–Barrandian Unit, two phases of tectonic development can be distinguished. During the Cambrian, the Příbram–Jince and Skryje–Týřovice basins (together with other sedimentary basins) were established and their infill rests with an angular unconformity on the Cadomian basement. The sedimentary record of the Prague Basin (opened in the early Ordovician) represents the second phase. The volcano–sedimentary sequences of the Prague Basin are overlying both the Cambrian and Precambrian rocks with an angular unconformity (e.g. Havlíček & Šnajdr 1951, Havlíček 1981).

During the Variscan Orogeny, the Teplá–Barrandian Unit has become one of the constituting parts of the newly formed Bohemian Massif (see Žák *et al.* 2014 and references therein). Some parts of the Teplá–Barrandian Unit are covered by volcano–sedimentary units which have originated after the Variscan Orogeny. These include terrestrial sequences of permocarboniferous basins, largely marine deposits of the Bohemian Cretaceous Basin and Cenozoic fluvial sediments.

3.1.1 Barrandian area

The term Barrandian area has been utilized for over a century. Herein, the term is understood in the sense of definition provided by Chlupáč and Štorch (1992, p. 259), where the Barrandian area is described as: "unmetamorphosed and weakly metamorphic Proterozoic and Paleozoic sequences (Cambrian to Devonian) in the Central and Western Bohemia.".

Herein, only selected stratigraphic levels of the Příbram–Jince and Prague basins are discussed in detail.

3.1.1.1 Příbram–Jince Basin

The Příbram–Jince Basin is interpreted to represent a structure formed on the margin of the Gondwana continent during the Cambrian (Drost *et al.* 2004); the basin is usually characterized as an intermontane–type depression (Havlíček 1971). Its origin has been explained as a result of a polyphase region–wide change of tectonic regime from convergent to transtensional (e.g. Drost *et al.* 2004). The infill of the Příbram–Jince Basin is supposed to be an up to 2500 meters thick sequence of prevailing clastic rocks (Havlíček 1971).

The volcano–sedimentary succession is partly covered by the Strašice Volcanic Complex, which originated during the late Cambrian to early Ordovician (e.g. Havlíček 1981, Drost *et al.* 2004). The sedimentary record of the Příbram–Jince Basin is usually divided into eight major litostratigraphic units classified as formations (Havlíček 1971). Typical lithologies throughout most of the sedimentary sequence are conglomerates, sandstones, and greywackes (Havlíček 1971).

The sedimentary environment of the Příbram–Jince Basin has been interpreted as continental with two notable exceptions – some levels of the Holšiny–Hořice Formation (most importantly the Paseky Shale Member) and the Jince Formation, together with the uppermost part of the underlying Chumava–Baštiny Formation (and possibly some other levels of the Chumava–Baštiny Formation as well; Kukal 1971). These two levels (the Paseky Shale Member and the interval between the uppermost Chumava–Baštiny Formation and the uppermost Jince Formation) are also the only known fossiliferous levels of the Příbram–Jince Basin (Fatka & Szabad 2014).

3.1.1.2 Prague Basin

The Prague Basin is a structure located in the Teplá–Barrandian Unit. The infill of the Prague Basin is mainly represented by diverse sedimentary and volcanic rocks of Early Ordovician to Middle Devonian age. Throughout the history of the Prague Basin, the development of its facies was influenced by both global and region–scale events, as well as by local tectonic settings (e.g. Havlíček 1981, Chlupáč & Kukal 1988).

The Prague Basin, interpreted as a rift basin, opened during the Early Ordovician as a reaction to the extension across the peri–Gondwana region. These processes have been linked to the closure of the Iapetus Ocean and the opening of the Rheic Ocean (Žák *et al*. 2013). The end of deposition of the infill of the Prague Basin is related to the Variscan Orogeny (see for example Kukal & Jäger 1988). During the orogeny, the entire area of the Prague Basin has been deformed into a form of a syncline–like structure; the deformation of the Prague Basin has recently been studied by Vacek & Žák (2019).

In current coordinates the longest axis of the structure has an approximately NE–SW direction. Its recent state is a denudation relict cropping out approximately 100 kilometres in length (reaching from Starý Plzenec in the southwest to Úvaly near Prague in the northeast; Havlíček 1981).

4. Studied stratigraphic levels

4.1 Cambrian

The first paleozoic system, Cambrian is divided into four series (Terreneuvian, Series 2, Miaolingian and Furongian), subdivided into ten stages (for summary see Geyer 2019). Herein, all studied samples of Cambrian age come from sediments of the Příbram–Jince Basin, namely from the Paseky Shale Member of the Holšiny–Hořice Formation and from the Jince Formation (see Fig. 1).

4.1.1 Holšiny–Hořice Formation

The Holšiny–Hořice Formation is the third lithostratigraphic unit of the infill of the Příbram–Jince Basin. The volcano–sedimentary sequence of the Holšiny–Hořice Formation is up to 1100 metres thick, predominantly consisting of conglomerates and sandstones. The formation is usually divided into three litostratigraphic units: the Holšiny Conglomerate, the Hořice Sandstones, and the Paseky Shale (Havlíček 1971).

4.1.1.1 Paseky Shale Member

4.1.1.1.1 Lithology and geological setting

The Paseky Shale Member is represented by a several metres thick sequence of fine–grained siliciclastic rocks embedded inside the Hořice Sandstones or the Holšiny Conglomerates of the Holšiny–Hořice Formation (Havlíček 1971). Originally, the rocks of the Paseky Shale Member were assigned to the Jince Formation (Kettner 1917, 1925 – for discussion see Fatka & Szabad 2014); their relation to the Holšiny–Hořice Formation has been recognized by Havlíček (1968). The Paseky Shale consists of greywackes and shales of typically green to grey green colour. In the upper parts, the sediment turns gradually coarser (Chlupáč *et al.* 1995, Kukal 1995).

The Paseky Shale Member has been studied in several outcrops across the Příbram–Jince Basin. Five localities studied in most detail up to now are Kočka Hill, Tok Hill, Medalův mlýn, Nepomuk and Pičín (Chlupáč *et al.* 1995). The localities differ in both abundance and diversity of macrofossils, microfossils and ichnofossils preserved. The locality Kočka Hill has provided, so far, most material in both macrofossil as well as microfossil record

(Chlupáč *et al*. 1995, Fatka & Konzalová 1995, Mikuláš 1995, Fatka *et al*. 2004, Fatka & Valent 2019).

4.1.1.1.2 Biostratigraphy and macrofossil record

Fauna

The macrofossil record of the Paseky Shale Member is restricted to three species of arthropods endemic to the Paseky Shale and several other organisms. Together, these taxa constitute the *Kodymirus* Association (Fatka & Szabad 2014). The most abundant arthropod species found in the Paseky Shale is *Kodymirus vagans*. It has been proposed that *Kodymirus vagans* might be related to aglaspidids (e.g. Chlupáč & Havlíček 1965, Lamsdell *et al*. 2013) or to eurypterids (e.g. Bergström 1968, Chlupáč 1995). Based on the occurrence of the taxon, the *Kodymirus vagans* Taxon–range Zone has been established; currently, this biozone is the only biostratigraphic unit distinguished in the Holšiny–Hořice Formation (Fatka & Szabad 2014).

Another arthropod species described from the Paseky Shale is *Kockurus grandis*. This species is of unknown taxonomic affinity; however, its morphology shares many characteristics with *Kodymirus vagans* (Chlupáč 1995).

The third arthropod species of the Paseky Shale Member is *Vladicaris subtilis*, a bivalved crustacean, possibly related with phyllocarids (Chlupáč 1995).

Apart from macroscopic remains, there is another kind of fossil record expanding the taxonomic diversity of arthropods in the Paseky Shale. SCFs have been described and interpreted as fragments of appendages of copepod crustaceans (Fatka & Konzalová 1995). Small fragments of arthropod remains (some assigned to *Kodymirus vagans* or *Vladicaris subtilis*) have also been distinguished inside bromalites (=fossilized products of digestion; Mikuláš 1995).

Apart from arthropods, *Eldonia*–like fossils and hyolithids are known from the Paseky Shale Member (Fatka & Szabad 2014, Fatka & Valent 2019). Furthermore, presence of another vagile benthic organism (possibly some kind of worm–like metazoan) has been proposed based on the presence, size, and content of the bromalites (Mikuláš 1995).

Algae

Remains of the algae *Marpolia spissa* Wallcot, 1919 have been described by Steiner & Fatka (1996).

4.1.1.1.3 Ichnofossil record

Kočka Hill is the only outcrop of the Paseky Shale that has yielded ichnofossils so far. The ichnofossil record has been summarized by Mikuláš (1995). The majority of ichnogenera described from the Paseky Shale have been attributed to *Kodymirus vagans* and *Kockurus grandis*. Among these, the ichnogenera *Dimorphichnus*, *Monomorphichnus* and *Rusophycus* can be found. The specimens assigned to the ichnogenus *Diplichnites* have been interpreted as possibly related to *Kodymirus vagans* and *Kockurus grandis*, but these traces could have also been caused by some other unknown arthropod or even a worm–like metazoan. Alongside the previously mentioned fossils, two other forms of ichnofossils are occurring in the Paseky Shale – *Bergaueria* and bromalites. The former is interpreted as burrows or cubichnia of hydrozoans, while the later was possibly produced by a worm–like benthic organism (as mentioned above) (Mikuláš 1995).

4.1.1.1.4 Microfossil record

Organic–walled microfossils (OWMs) extracted from the Paseky Shale have been studied previously (e.g. Fatka & Konzalová 1995). By far the most abundant are various filamentous microfossils, represented by the following seven genera: *Botuobia*, *Palaeolyngbya*, *Polytrichoides*, *Rectia, Siphonophycus*, *Spiromorphes* and *Tortunema* (Fatka & Konzalová 1995, Steiner & Fatka 1996). The elements assigned to the genera *Polytrichoides*, *Siphonophycus* and *Tortunema* have been interpreted as constituent parts of disintegrated alga *Marpolia spissa* (Steiner & Fatka 1996).

Several genera of acritarchs have been reported from the Paseky Shale: *Adara*, *Leiosphaeridia*, *Retisphaeridium*, *Sinianella*, *Skiagia*. Specimens possibly belonging to the acritarch genera *Aliumella* and *Volkovia* have also been documented. Moreover, elements assigned to the acritarch genus *Ceratophyton* have been reported. Fatka & Konzalová (1995) have interpreted the recovered elements of *Ceratophyton* as appendages of Copepods.

Based on the specific macro– and microfossil record, ichnofossils and sedimentology of the Paseky Shale Member, it is supposed that the Paseky Shale represent a record of shallow, restricted marine environment. The macrofauna of the Paseky Shale therefore most probably represents some of the oldest known macrofaunal remains in the Bohemian Massif as well as the oldest known macrofauna of brackish environment (Chlupáč 1995, Kukal 1995, Mikuláš 1995).

The chronostratigraphic position of the Paseky Shale Member (and consequently of the entire sedimentary succession of the Příbram–Jince Basin below the base of the *Westonia? fatkai* Interval Zone – see Chapter 4.1.2) is unclear, although it has been proposed that the Paseky Shale Member might belong to the upper part of the Cambrian Series 2. This has been based on the occurrence of the acritarch *Volkovia*. The age determination is not certain, however, because of poor preservation of the respective specimens (Fatka & Konzalová 1995, Fatka & Szabad 2014).

4.1.2 Jince Formation

4.1.2.1 Lithology and geological setting

The Jince Formation, situated in the upper part of the infill of the Příbram–Jince Basin, consists of a sequence of mostly fine–grained siliciclastic rocks (mainly shales, greywackes, and fine sandstones; Havlíček 1971). Based on faunal assemblages and lithological changes, three biofacies have been recognised reflecting relative sea level changes in time (the Agnostid Biofacies, the Trilobite Biofacies and the *Lingullela* Biofacies). The biofacies also change laterally. The *Lingullela* Biofacies represents shallow–water assemblages, the Trilobite Biofacies developed in normal marine environment, and the Agnostid Biofacies was only present in the deepest parts of the basin during its maximal deepening (Fatka & Szabad 2014).

4.1.2.2 Biostratigraphy and macrofossil record

Since the second half of the 19th century, several biostratigraphic divisions of the Jince Formation have been proposed (for summary see Fatka 2003). The most detailed scheme so far has been elaborated by Fatka & Szabad (2014). According to this division, the base of the Jince Formation (together with the uppermost levels of the underlying Chumava–Baština Formation) corresponds to the *Westonia*? *fatkai* Interval Zone, defined by the first appearance date (FAD) of the brachiopod species *Westonia*? *fatkai*, at its base and the FAD of trilobite *Acadolenus snajdri*, as its upper limit. The biozone is represented by a low–diversity brachiopod association, containing fossils of *Westonia*? and *Botsfordia*.

The second zone is the *Acadolenus snajdri* Interval Zone. The base of the zone is defined by the FAD of the trilobite *Acadolenus snajdri* and the zone ends with the FAD of the trilobite species *Paradoxides* (*Eccaparadoxides*) *pusillus*. This zone shows a higher diversity of brachiopods, trilobites and agnostids (although changing throughout the zone). Hyoliths and stylophorans have also been described. Within the lower parts of the *Acadolenus snajdri* Zone, the *Sternbergaspis brdensis* Taxon–range Zone has been established as a subzone.

Following is the *Paradoxides* (*Eccaparadoxides*) *pusillus* Interval Zone. Its lower and upper boundaries are defined by the FAD of the trilobite *Paradoxides* (*Eccaparadoxides*) *pusillus* and the FAD of the agnostid *Onymagnostus hybridus*, respectively. The sediments contain diverse association of trilobites and agnostids. Moreover, echinoderms, molluscs, sphenothallids and closer undetermined vermiform fossils have been described (Fatka *et al*. 2004, 2012). Within the *Paradoxides* (*Eccaparadoxides*) *pusillus* Interval Zone, the *Litavkaspis rejkovicensis* Taxon–range Zone has been defined as a subzone.

The lower boundary of the following *Onymagnostus hybridus* Interval Zone is defined by the FAD of agnostid *Onymagnostus hybridus*. The upper boundary of the zone is defined by the FAD of agnostid *Hypagnostus parvifrons*. The biozone is mainly occupied by a diverse agnostid and trilobite association together with brachiopods, echinoderms, and other organisms (including *Eldonia* and *Selkirkia*). Remains of closer undetermined vermiform organisms and spicules of hexactinellid sponges have also been described from this biozone (Fatka *et al*. 2004, Mergl & Fatka 2012). The *Onymagnostus hybridus* Interval Zone overlaps (variously in different parts of the basin) with the *Dawsonia bohemica* Taxon–range Zone.

The *Hypagnostus parvifrons* Interval Zone´s lower and upper boundary have been established based on the FAD of the eponymous agnostid and the FAD of trilobite *Paradoxides* (*Paradoxides*) *paradoxissimus gracilis*, respectively. Fossils are generally rare in this biozone.

A significant portion of the two previously mentioned zones (the *Onymagnostus hybridus* Interval Zone and the *Hypagnosthus parvifrons* Interval Zone) does correspond to the Barren interzone between *Paradoxides* (*Eccaparadoxides*) *pusillus* and *Paradoxides*

(*Paradoxides*) *paradoxissimus gracilis*. Although called Barren interval, it contains specimens of several agnostid species as well as trilobites. Other arthropods (e.g. bradoriid *Konicekion* or bivalved arthropod *Tuzoia*) and echinoderms have also been described.

The following biozone is the *Paradoxides* (*Paradoxides*) *paradoxissimus gracilis* Taxon–range Zone, containing diverse trilobite, agnostid and echinoderm associations alongside bradoriids and sphenothallids (Fatka *et al*. 2012).

The youngest biostratigraphical unit defined in the Jince Formation is the *Ellipsocephalus hoffi–Lingulella–Paradoxides* (*Rejkocephalus*) Interval Zone delimited by the last appearance date (LAD) of the trilobite species *Paradoxides* (*Paradoxides*) *paradoxissimus gracilis* and the LAD of the brachiopod genus *Linguella*. Diverse trilobites have been described as well as agnostids, bivalved arthropods. Pterobranchs, echinoderms and brachiopods have also been reported from this zone (Fatka & Szabad 2014).

The fossil record of the Jince Formation has been summarized in detail by Fatka et al. (2004).

Several levels of the Jince Formation have been described as *Konservat–Lagerstätten* for their content of exceptional fossil record, including preservation of unmineralized arthropods and other rare fossils (e.g. Chlupáč & Kordule 2002, Fatka *et al*. 2011a, Mikuláš *et al*. 2012).

4.1.2.3 Ichnofossil record

The ichnofossil record of the Jince Formation has been summarized by Mikuláš (2000, 2002). Generally, the nearshore depositional environments are represented by ichnofossils constituting the *Skolithos* Ichnofacies, such as *Daedalus*, *Diplocraterion*, *Skolithos*, "*Thalassinoides*". The composition of assemblages reflecting the shallow environments does differ in individual stratigraphic levels of the Jince Formation (Mikuláš 2000).

A significant portion of the Jince Formation (mainly the deeper–water facies) is represented by ichnoassemblages corresponding to the *Cruziana* Ichnofacies, containing mainly the ichnogenera *Daedalus*, *Palaeophycus*, *Planolites*, *Teichichnus* and *Thalassinoides*, alongside coprolites. In certain levels, the assemblage is complemented by other ichnogenera (e.g. *Rejkovicichnus*; Mikuláš 2000).

Furthermore, Mikuláš *et al*. (2012) have described a specific set of ichnofossils associated with fossils of slightly to non–biomineralized arthropods.

4.1.2.4 Microfossil record

The microfossil record of the Jince Formation has so far been studied by several authors. The majority of the published research has been focused on organic–walled microfossils (mainly acritarchs), but foraminifera have been described from the Jince Formation as well (see below).

Organic–walled microfossils

Several acritarch genera have been documented from the *Ellipsocephalus hoffi-Lingulella-Paradoxides* (*Rejkocephalus*) Interval Zone by Slavíková (1968). Among those are the genera *Comasphaeridium*, *Cymatiosphaera*, *Dictyotidium*, *Leiosphaeridia*, *Lophosphaeridium*, *Micrhystridium*, *Polyedrixium*, *Retisphaeridium*, *Solisphaeridium* and *Symplassosphaeridum*.

Vavrdová (1982a) has reported the acritarch genera *Acanthodiacrodium*, *Cristallinium*, *Dodylofusa*, *Eliasum*, *Leiofusa*, *Leiosphaeridia*, *Lophosphaeridium*, *Micrhystridium* and *Timofeevia* from the *Paradoxides* (*Eccaparadoxides*) *pussilus* Zone (see Fatka & Szabad 2014 for correlation).

From the *Onymagnostus hybridus* Interval Zone, numerous acritarch genera have been described by Fatka (1989): *Adara*, *Alliumella*, *Annulum*, *Archaeodiscina*, *Comasphaeridium*, *Cristallinium*, *Cymatiosphaera*, *Eliasum*, *Hemisphaeridium*, *Liepaina, Leiosphaeridia*, *Lophosphaeridium*, *Micrhystridium*, *Multiplicisphaeridium*, *Skiagia*, *Synsphaeridium* and *Timofeevia*. Moreover, algal filaments have been documented. Selected genera of microfossils originating from the *Onymagnostus hybridus* Interval Zone have been studied by Tonarová (2006).

Foraminifera

Thuramminoides, a genus of agglutinated foraminifera has been described from the *Litavkaspis rejkovicensis* Taxon–range Zone and the *Onymagnostus hybridus* Interval Zone (Bubík 2001; see Fatka & Szabad 2014 for correlation).

4.2 Ordovician

Ordovician is the second system of the Paleozoic. Globally, Ordovician is divided into three series (Lower, Middle and Upper Ordovician) and seven stages (for summary see Bergström *et al*. 2009). In the Mediterranean Province (including the Bohemian Massif), the Bohemo–Iberian regional chronostratigraphical scale is often utilized for classification of rock sequences. This regional scale divides the timespan of the global stages Floian through Katian into five regional stages (see Havlíček *et al*. 1994, Gutiérrez–Marco *et al*. 2017).

The Ordovician infill of the Prague Basin is mainly represented by siliciclastic sediments and basic volcanic rocks. The volcano–sedimentary sequence has been divided into twelve litostratigraphic units classified as formations (see Fig. 1). Herein, only two of the units, the Letná and Kosov formations are studied and thus only these units will be discussed in detail.

4.2.1 Letná Formation

4.2.1.1 Lithology and geological setting

The Letná Formation was deposited during the regional Berounian Stage, approximately corresponding to the Sandbian Stage of the Late Ordovician (Fatka & Mergl 2009). The thickness of the Letná Formation exceeds 600 meters in the central parts of the Prague Basin (Mikuláš 1998). The formation consists prevalently of rhythmically alternating sandstones, greywackes, and silty shales. During diagenesis, some of the coarser sediments were silicified (Kukal 1957).

The base of the Letná Formation is defined by the onset of the typical rhythmic sedimentation, interpreted as a consequence of variations in material supply brought by rivers to the basin (Kukal 1957) and/or storm activity (Mikuláš 1998). Generally, relatively shallow water sediments are located in the north–western part of the Prague Basin (with some parts even being periodically emerged above the sea surface), while the south–eastern part is represented by comparatively deeper–water facies (Kukal 1957).

Changes in lithological content at the upper boundary of the Letná Formation have been interpreted to reflect the transgressive Lower Caradocian Event (Chlupáč & Kukal 1988).

4.2.1.2 Macrofossil record

Macroscopic fossils are distributed unevenly in the Letná Formation, with significant portions of the formation being sparsely fossiliferous to unfossiliferous (Havlíček & Vaněk 1966).

Sequences consisting mainly of dark shales, interpreted as deposits of the deeper parts of the basin, contain a fossil assemblage consisting of the following trilobite genera: *Deanaspis*, *Girvanopyge*, *Heterocyclopyge*, *Opsimasaphus*, *Prionocheilus*, *Selenopeltis* and *Zeliszkella* (Havlíček & Vaněk 1990). These fossils have been assigned to the atheloptic trilobite association and the Cyclopygid Biofacies by Fatka & Mergl (2009). Fatka *et al*. (2013) have also reported presence of closer unidentified graptolites co–occuring with trilobites of the atheloptic trilobite association. Furthermore, the presence of the deep–water brachiopod *Paterula* Association in sediments of the deepest parts of the basin has been mentioned by Mergl (1999) and Fatka *et al*. (2013).

Significantly more diversified *Drabovia redux* Community has been documented from sandstones of the upper parts of the Letná Formation (and locally from the lower portions of the Letná Formation as well; Havlíček 1982). The most significant components of the community are the brachiopod genera *Drabovia* and *Drabovinella*, trilobite genera *Dalmanitina* and *Deanaspis*, alongside *Birmanites*, *Calymenella*, *Eccoptochile*, *Onnia*, and *Selenopeltis*, echinoderm genera *Ascocystites*, *Macrocystella*, and *Hemicystites*, conulariids *Ananoconularia* and *Metaconularia*, bivalves *Cuneamya*, *Modiolopsis* and other taxa (Havlíček & Vaněk 1966, Havlíček 1982, Fatka *et al*. 2013, Polechová 2019).

Several genera of rare arthropods have been described from the sandstones of the upper part of the Letná Formation (see Chlupáč 1965, 1999). Many of these arthropods are of problematic taxonomic position. These taxa include a possible aglaspidid genus *Zonozoe*, incertae sedis *Zonoscutum*, a tentative phyllocarid crustacean *Nothozoe*, the xiphosuran *Drabovaspis* (see Bergström 1968, Ortega–Hernández 2010), a possible aglaspidid or trilobite *Caryon* (see Hou & Bergström 1997, Ortega–Hernández *et al*. 2010), the chelloniellid arthropod *Triopus* (see Van Roy 2005, Ortega–Hernández *et al*. 2010), the 'aglaspidid–like' *Chacharejocaris*? (see Van Roy 2005), possible marrelomorph *Furca* and the chellonielid *Duslia* (see Chlupáč 1988). Furthermore, fragmentary remains of a large arthropod of possible eurypterid affinity have been documented by Chlupáč (1999).

Havlíček (1982) has distinguished the *Bicuspina* Community in greywackes of the uppermost Letná Formation. The community constitutes of (among others) trilobite genera *Pharostoma* and *Stenopareia*, brachiopods *Aegiromena*, *Bicuspina*, *Dactylogonia*, *Hirnantia* and *Mesodalmanella*, and echinoderms *Dendrocystites*, *Mimocystites*, *Rhombifera* (Havlíček & Vaněk 1966, Havlíček 1982) The *Bicuspina* Community has been interpreted to occupy deeper environment than the *Drabovia redux* Community (Havlíček 1982).

Fatka & Mergl (2009) and Fatka *et al*. (2013) have used the term *Drabovia–Aegiromena* fauna to describe the two communities (*Drabovia redux* and *Bicuspina* communities) and have distinguished a separate near–shore association consisting of non–trilobite arthropods, abundant trilobites *Dalmanitina* and *Deanaspis* and trematid brachiopods; for the fossil record of individual levels containing the non–trilobite arthropods in the Letná Formation see Chlupáč (1965).

The fauna of the Letná Formation has been summarized by Havlíček & Vaněk (1966). Further published research of the macroscopic fossil record of the Letná Formation includes Havlíček & Vaněk (1990), Chlupáč (1988, 1999), Schallreuter & Krůta (2001), nohe *et al*. (2009), Fatka *et al*. (2013), Polechová (2019) and other.

Several levels of the Letná Formation have been described as either *Konservat–Lagerstätten* (for their content of rare, lightly biomineralised arthropods) or *Konzentrat–Lagerstätten* (e.g. Fatka *et al*. 2011a, Nohejlová *et al*. 2019).

4.2.1.3 Ichnofossil record

The lower portions of the Letná Formation are represented by a low–diversified ichnoassemblage consisting of the genera *Chondrites*, *Diplocraterion*, *Phycodes*, *Planolites*, *Protopaleodictyon*, *Megagrapton* and *Teichichnus*. The assemblage has been interpreted to reflect poor ecological conditions, especially low oxygen content in both water and sediment (Mikuláš 1998).

The upper levels of the Letná Formation are occupied by another, more diversified ichnoassemblage containing the genera *Cruziana*, *Curvolithus*, *Didymaulichnus*, *Palaeophycus*, *Planolites*, *Rusophycus*, *Rhizocorallium*, *Teichichnus*, alongside abundant unidentifiable bioturbation. This ichnoassemblage corresponds to the *Cruziana* Ichnofacies and proves the presence of a more diverse biota in this part of the formation.

Various ichnogenera have also been reported to co–occur with the above mentioned ichnofossils locally (e.g. *Arenicolites*, *Bifungites*, *Buthothrepis*; Mikuláš 1998).
Presence of other ichnoassemblages has been reported from the Letná Formation (e.g. an assemblage, consisting of abundant *Bergaueria* fossils described from the uppermost parts of the Letná Formation), but these assemblages are present only locally (Mikuláš 1998).

4.2.1.4 Microfossil record

The number of studies dedicated to microfossils of the Letná Formation is relatively limited. The microfossil record consists of organic–walled microfossils.
Čorná (1969) has reported the acritarch genus *Veryhachium* and the chitinozoan genera *Angochitina*, *Conochitina* and *Desmochitina* from the Letná Formation. Moreover, leiospheres and a specimen of the acritarch *Micrhystridium* have been figured (Čorná 1969, p.408, Plate 8, figs. 10 – 12).
Vavrdová (1986) has described the following acritarch genera: *Cheleutochroa*, *Multiplicisphaeridium*, *Piliferosphaera*, *Tylotopalla* and *Veryhachium*.
Fialová (1998) has studied in detail fossil record of the genera *Micrhystridium* and *Veryhachium* present in the Letná Formation.
Chitinozoan genera *Angochitina*?, *Belonechitina*, *Conochitina*, *Cyathochitina*, *Desmochitina*, *Euconochitina*, *Hercochitina*, *Hyalochitina*?, *Lagenochitina*, *Laufeldochitina*, *Linochitina*, *Pistallachitina*?, *Rhabdochitina*?, *Spinachitina* and *Tanuchitina* have been documented by Vodička & Fatka (2017).

4.2.2 Kosov Formation

4.2.2.1 Lithology and geological setting

The Kosov Formation represents the youngest unit of the Ordovician infill in the Prague Basin. Its age corresponds to the Hirnantian Stage of the Late Ordovician (Štorch & Mergl 1989). The development of the sedimentary record has been interpreted to reflect global climatic changes that occurred in this time interval (e.g. occurrence of dropstones) together with the local tectonic changes (Štorch & Mergl 1989).
The thickness of the Kosov Formation varies between 40 to 120 metres. The base of the Kosov Formation is marked by an increase of coarse–grained component in sediment,

resulting in layers of greywacke interlayered with mudstones. This portion of the succession has been interpreted as deposited by mudflows. The lower part of the Kosov Formation consists mainly of silty shales with local sandy intercalations. The interval with silty shales is overlain by greywackes and mudstones. This part of the succession is then followed by a sequence of alternating coarser and more fine–grained siliciclastic rocks. The upper part of the Kosov Formation consists of poorly sorted greywackes, coarse sandstones, and conglomerates. The succession is closed by a sequence of siltstones and mudstones (Štorch & Mergl 1989, Mikuláš 1992).

4.2.2.2 Macrofossil record

Fauna

Macroscopic body fossils are only restricted to some levels of the Kosov Formation (Havlíček & Vaněk 1966).

From the lower parts of the Kosov Formation, the *Mucronaspis* Assemblage has been documented. It consists of the eponymous trilobite and fragmentary brachiopods. The assemblage is comparatively poorer than its equivalent in the uppermost part of the underlying Králův Dvůr Formation (Štorch & Mergl 1989).

In the upper part of the Kosov Formation the low diversity but high abundance *Modiolopsis pragensis* Community Group occupies sandstone facies interpreted to represent high energy, shallow water depositional environment (see Havlíček 1982, Kříž & Steinová 2009). The most prevalent fossils of this assemblage are bivalves belonging to the genus *Modiolopsis*. Alongside the eponymous genus, the assemblage consists of other bivalves (*Metapalaeoneilo* and *Myoplusia*), gastropods (*Bucanella*), rostroconchs (*Ribeiria*) and brachiopods (*Aegiromena* and *Plectothyrela*). Arthropods are represented by the trilobite *Brongniartella* and the phyllocarid *Ceratiocaris*. Moreover, sponge spicules and remains assigned to the genus *Cornulites* have also been described (Havlíček 1982, Kříž & Steinová 2009).

In the uppermost part of the Kosov Formation, the diverse *Hirnantia saggitifera – Sluha kosoviensis* Community occurs (Havlíček 1982, Kříž & Steinová 2009). This association includes diverse brachiopods (e.g. *Cryptothyrella*, *Drabovia*, *Hirnantia*, *Rafanoglossa*, *Schizotretinia*, *Tethytere*), trilobites (e.g. *Brongniartella*, *Mucronaspis*). Molluscs are represented by various bivalve genera (*Modiolopsis*, *Myoplusia*, *Mytilarca*, *Nuculites*, *Praeleda*, *Praenucula*, *Sluha* and ?*Sphenolium*) and gastropods (*Bucanella*, *Grandostoma*, *Sinuitopsis* and *Temnodiscus*) (Štorch 1986, Kříž & Steinová 2009). The presence of various other groups (including annelids, bryozoans, conulariids, echinoderms, hyolithids, ostracods and phyllocarids) has been reported, but the fossils have not been revised so far (see Marek 1951, Štorch 1986, Kříž & Steinová 2009). The onset of the community has been interpreted to reflect deepening of the depositional environment (Havlíček 1982).

The presence of the graptolite *Normalograptus persculptus* has been documented in the lowermost and uppermost levels of the Kosov Formation (Havlíček & Vaněk 1966, Štorch & Loydell 1996).

Algae

The algal genus *Ischadites* has been reported from the uppermost portions of the Kosov Formation (locality unknown; e.g. Havlíček 1982).

4.2.2.3 Ichnofossil record

Seven ichnofossil assemblages interpreted to reflect bathymetrical changes of the depositional environment have been distinguished in the Kosov Formation (Mikuláš 1992).

The oldest assemblage has been established in muddy layers in the lower–most portion of the Kosov Formation (co–occurring with body fossils belonging to the *Mucronaspis* Assemblage). The ichnofossil assemblage contains abundant ichnogenera *Arthraria*, *Bifungites* and *Planolites*.

The following assemblage occupies shales and siltstones in the lower levels of the Kosov Formation. This assemblage consists of ichnogenera *Arthraria*, *Asteriacites*, *Bifungites*, *Laevicyclus*, *Monofungites*, *Planolites*, ?*Rhabdoglyphus* and *Torrowangea*. For this assemblage, low diversity of benthic organisms and relation to environment below fair wave base is supposed (Mikuláš 1992).

The third assemblage occurrs in sandstones and silty shales and contains numerous ichnogenera, like *Arthraria*, *Asteriacites*, *Aulichnites*, ?*Beaconichnus*, *Cruziana*, *Curvolithus*, *Gordia*, *Isopodoichnus*, *Laevicyclus*, *Monofungites*, *Monomorphichnus*, *Palmichnium*, *Phycodes*, *Planolites*, *Protopaleodyction*, ?*Rhabdoglyphus*, *Rhizocorallium*, *Rusophycus*, *Scalarituba*, *Taphrhelminthopsis*, *Treptichnus* and

Torrowangea. This assemblage has been interpreted to represent shallow–water environment. Some of the ichnofossils also hint at presence of biomineralizing organisms although these are unknown as body–fossils (Mikuláš 1992).
The succeeding ichnoassemblage is characteristic for shales and siltstones and stratigraphically overlies the preceding assemblage. The ichnofossils are rarer in this assemblage. Following ichnogenera have been described: ?*Corophioides*, *Curvolithus*, *Planolites*, *Taphrhelminthopsis* and *Torrowangea*.
The next assemblage is typical for sandstones and conglomerates of the upper levels of the Kosov Formation. Ichnofossils are generally rare and include *Arenicolites*, *Monocraterion* and *Planolites*. The association has been interpreted as related to very shallow environment (Mikuláš 1992).
The sixth assemblage has been distinguished in rhythmically changing sedimentary succession overlying the fifth assemblage. Ichnogenera *Asteriacites*, *Gyrochorte*, *Interruptida*, ?*Lockeia* and *Planolites* have been described.
The last ichnofossil assemblage has been recognized in shales of the uppermost Kosov Formation. The assemblage consists of *Cilindrotomaculum* and ?*Rhabdoglyphus* as well as some closer undetermined ichnofossils.

4.2.2.4 Microfossil record

Scolecodonts (*Arrabelites*) and conodonts (*Priniodus*) have been reported from the uppermost part of the Kosov Formation by Marek (1951).
Vavrdová (1982b, 1984, 1988, 1989) has documented more than two hundred species of palynomorphs from the uppermost levels of the Kosov Formation at Hlásná Třebáň. The palynomorph spectrum includes diverse cryptospores, plant remains (including sheets of polygonal cells, cellular sporangia and tracheids) and various acritarchs (ranging from early Cambrian to late Ordovician age); some of the acritarchs have been interpreted as redeposited.
Various organic–walled microfossils have been described from the uppermost part of the Kosov Formation by Dufka & Fatka (1993). These include acritarch genera ?*Ammonidium*, ?*Arkonia*, *Asketopalla*, *Baltisphaeridium*, *Dictyotidium Diexallophasis*, *Eupoikilofusa*, *Gorgonisphaeridium*, *Leiosphaeridia*, *Multiplicisphaeridium*, *Neoveryhachium*, *Ordovicidium*, *Orthosphaeridium*, ?*Palaiosphaeridium*, *Petaloferidium*, *Striatotheca*, *Tylotopalla*, ?*Uncinisphaera*, *Veryhachium*, *Villosacapsula*

and *Visbysphaera*. Two genera of chitinozoans, namely *Conochitina* and *Lagenochitina*, have also been reported from the Kosov Formation (Dufka & Fatka 1993).

4.3 Devonian

The Devonian system is the fourth system of Paleozoic. Globally, it is divided into the series Lower, Middle and Upper series which are subdivided into seven stages (see Ziegler & Klapper 1985). In the Barrandian area, the third stage (Emsian) is replaced by two regional stages (Zlíchovian and Dalejan) by some authors (e.g. Chlupáč *et al*. 2000).

Herein, only two stratigraphic levels of the infill of the Prague Basin will be discussed in detail – the Daleje Shale Member of the Daleje–Třebotov Formation and the Roblín Member of the Srbsko Formation (see Fig. 1).

4.3.1 Daleje–Třebotov Formation

The Daleje–Třebotov Formation is a part of the Devonian sequence of the Prague Basin. The age of the unit approximately corresponds to the regional Dalejan Stage (late Emsian) reaching to the early Eifelian. The Daleje–Třebotov Formation embraces three litostratigraphic units classified as members: the Daleje Shale, the Suchomasty Limestone, and the Třebotov Limestone (Chlupáč 1981). The formation mainly consists of carbonates (except for the Daleje Shale; see below).

4.3.1.1 Daleje Shale

4.3.1.1.1 Lithology and geological setting

The Daleje Shale Member consists mainly of green to green–grey shales locally containing micritic limestones. In the upper levels, the green shales are interlayered with red coloured shales and carbonate layers (Chlupáč 1959).
The sequence of the Daleje Shale is up to 50 metres thick, although it is missing in some areas of the basin. The member has been interpreted as representing relatively deeper parts of the basin (Chlupáč 1959). The onset of the Daleje Shale has been interpreted to reflect the transgressive Daleje Event (Chlupáč & Kukal 1988).

4.3.1.1.2 Macrofossil record

Fauna

Based on research of trilobites, the *Phacops–Cyrtosymboloides* Assemblage has been recognised within the Daleje Shale. Together with the eponymous genera (*Cyrtosymboloides* and *Phacops*), the assemblage consists of the trilobite genera *Crotacephalus*, *Cheirurus*, *Macroblepharum*, *Otarionella*, *Leonaspis* and *Scabriscutellum* (Chlupáč *et al*. 1979, Chlupáč 1983). Further arthropods are represented by the thylacocephallid *Concavicaris* and the phyllocarid *Kockelites* (see Chlupáč *et al*. 1979).

Molluscs are represented by cephalopods (*Amoenophyllites*, *Anetoceras*, *Palaeogoniatites*, *Gyroceratites*, *Orthoceras*, *Mimogoniatites*, *Mimosphinctes* and *Teicherticeras*; Chlupáč 1959, Chlupáč & Turek 1983), gastropods (*Raphistomina*) and bivalves (*Buchiola*, *Cardium*, *Gibbopleura*, *Isocardia*, *Lunulicardium*, *Panenka*, *"Pterochaenia"* and *Služka*; Chlupáč *et al*. 1979). Hyoliths assigned to the genus *Orthotheca* have been documented by Chlupáč (1959). Tentaculites belonging to the genera *Anoplotheca*, *Costulatostyliolina*, *Homoctenus*, *Metastyliolina*, *Nowakia*, *Stiatostyliolina*, *Styliolina*, *Viriatellina* have been described by Chlupáč *et al*. (1979).

The Daleje Shale contain the following brachiopod genera: *Chonetes*, *Chynistrophia*, *Cingulodermis*, *Clorinda*, *Dalejina*, *Dalejodiscus*, *Elliptostrophia*, *Lochkothele*, *Merrista*, *Orbiculoidea*, *Orthocrinus*, *Paraplicanoplia*, *Prodavidsonia*, *Prokopia*, *Rugoleptaena* and *Strophochonetes* (Chlupáč *et al*. 1979, Mergl 2001).

Chlupáč (1959) has described several genera of corals from the Daleje Shale: *Syringaxon*, *Petraia*, *Cladochonus*, *Favosites* and *Striatopora*.

The only documented genus of echinoderms is *Dalejocystis* (Chlupáč *et al*. 1979). Graptolites are represented by the dendroid *Dictyonema* (Chlupáč *et al*. 1979).

Flora

The following genera of fossil plants have been reported from the Daleje Shale: *Dalejophyton*, *Protolepidodendron* and *Protopteridium* (Obrhel 1956). Furthermore, presence of the algal genus *Ischadites* has been described (Chlupáč 1959, Obrhel 1968).

4.3.1.1.3 Ichnofossil record

The ichnofossil record of the Daleje Shale has not been systematically studied in detail. However, abundant specimens of the ichnogenus *Chondrites* have been reported from the Daleje Shale (e.g. Chlupáč 1983).

4.3.1.1.4 Microfossil record

The microfossils of the Daleje Shale have been studied by numerous authors. The fossils include various organic–walled microfossils, calcareous fossils, and conodonts.

Organic–walled microfossils

Several genera of acritarchs, prasinophytes and spores have been documented by Lele (1972). The acritarchs and prasinophytes are represented by the following genera: *Dictyotidium*, *Leiosphaeridia, Lophosphaeridium Pilasporites*, *Protoleiosphaeridium*, *Retisphaeridium*, ?*Tasmanites* and *Veryhachium*. Spores have been assigned by Lele (1972) to the genera *Ancyrospora*, *Aneurospora*, *Apiculatisporis*, *Apiculiretusispora, Biornatispora*, *Convolutispora*, *Cyclogranisporites*, *Dibolisporites*, Cf. *Grandispora*, *Granulatisporites*, *Leiotriletes*, *Punctatisporites*, *Samariporites* and *Verrucosisporites*.

Riegel (1974) has reported several acritarch genera: *Baltisphaeridium*, *Cymatiosphaera*, *Diexallophasis*, *Leiosphaeridia*, *Lophosphaeridium*, *Multiplicisphaeridium*, *Navifusa*, *Tasmanites* and *Veryhachium*.

McGregor (1979) has described following genera of spores from samples originating from several levels within the Daleje Shale: *Acinosporites*, *Anapiculatisporites*, *Apiculatasporites*, *Apiculatisporis* *Apiculiretusispora*, *Archaeozonotriletes*, *Camarozonotriletes*, *Clivosispora*, *Dibolisporites*, *Dictyotriletes*, *Emphanisporites*, *Grandispora*, *Hymenozonotriletes*, *Kraeuselisporites*, *Retusotriletes*, *Tholisporites* and ?*Verruciretusispora*.

Holcová (2002) has reported leiospheres from the Daleje Shale.

Brocke *et al*. (2004) have mentioned the presence of further unidentified "acritarchs, prasinophytes, chitinozoans, scolecodonts and spores" (Brocke *et al*. 2004, p. 148) and in a follow–up study, Fatka & Brocke (2008) have examined the acritarch *Navifusa* in detail.

Jarochowska *et al*. (2013) have published finds of the chitinozoan genera *Calpichitina* and *Ramochitina*, the scolecodont genera *Kettnerites*, *Lunoprionella* and *Oenonites* and prasinophytes.

Tonarová *et al*. (2017) have reported the chitinozoans *Ancyrochitina*, *Angochitina*, *Bulbochitina*, *Bursachitina*, *Desmochitina*, ?*Eisenackitina* and *Ramochitina*, scolecodonts *Hindenites*, *Kettnerites*, *Mochtyella* and *Oenonites*, and prasinophytes.

Foraminifera and shelly fossils

Holcová (2002) has documented the following genera of foraminifera: *Archaesphaeridae*, *Psammosphaera, Thuraminoides*, *Thurammina*, *Tolypammina*, associated with sponge spicules, closer undetermined podocopid ostracods, tentaculites and juvenile brachiopods.

Jarochowska *et al*. (2013) have demonstrated a microfossil extraction procedure utilizing surfactant Rewoquat on a sample from the Daleje Shale. The recovered fossils include tentaculites (*Nowakia*), ostracods (*Criboconcha*), fragments of trilobite exoskeletons and corals.

Conodonts

The conodont genera *Icriodus* and *Polygnathus* have been reported by Chlupáč *et al*. (1979).

The presence of the conodont *Pseudoonetodus* has been documented by Jarochowska *et al*. (2013).

4.3.2 Srbsko Formation

The Srbsko Formation is the youngest unit of the Prague Basin; it corresponds to the Givetian Stage. The formation is usually divided into two members – the Kačák Member and the Roblín Member (Kukal & Jäger 1988). The sedimentary record of the Srbsko Formation has been interpreted to reflect tectonic processes related to the early stages of the Variscan Orogeny (e.g. Kukal & Jäger 1988). Herein, only the Roblín Member will be discussed in detail.

4.3.2.1 Roblín Member

4.3.2.1.1 Lithology and geological setting

The major part of the Srbsko Formation is represented by sediments of the Roblín Member, embodied by an up to 250 metres thick sequence dominated by siltstones and sandstones of flysch–like character; this is also supported by its ichnofossil assemblage (Mikuláš & Pek 1996). It is presumed that the original thickness might have been bigger, but the uppermost portion has probably been eroded (Kukal & Jäger 1988). The Roblín Member overlies the dark shales of the Kačák Member (Kukal & Jäger 1988).

4.3.2.1.2 Macrofossil record

Fauna

The fossil fauna of the Srbsko Formation has been summarized by Chlupáč (1960). Additional data on occurence of cephalopods (Chlupáč & Turek 1983), brachiopods (Mergl 2001) and placoderms (Vaškaninová & Kraft 2014) has been published since then. The Roblín Member contains the *Aulacopleura* Assemblage consisting of *Aulacopleura*, *Helioharpes*, *Leonaspis* and *Phacops* (Chlupáč 1983, Chlupáč 1989).

Cephalopods are represented by the goniatite genera *Agoniatites* and *Holzapfeloceras* (Chlupáč & Turek 1983) and nautiloid genera *Kophinoceras* and *"Orthoceras"* (Chlupáč 1960). Chlupáč (1960) has reported bivalve genera *Allorisma*, *Buchiola* and *"Nucula"*. The Roblín Member also contains tentaculites *Nowakia* and *Styliolina* and hyoliths belonging to the genus *Orthotheca* (Chlupáč 1960).

Brachiopods are represented by *"Atrypa"*, *Chonetes* and *Chascothyris* (Chlupáč 1960).

Two genera of corals have been recovered: *Cladochonus* and *Striatopora* (Chlupáč 1960).

Fragmentary placoderm remains have been reported from the Roblín Member by Vaškaninová & Kraft (2014).

Flora

A summary of the fossil flora of the Roblín Member has been provided by Obrhel (1961, 1968). Plant remains assigned to the following genera have been reported: ?*Aneurophyton*, *Barrandeina*, *"Drepanophycus"*, *Dawsonites*, *Pseudosporochnus*, *Protolepidodendron*, *Protopteridium*, *Psilophyton* and ?*Zosterophyllum*. Moreover, two distinct forms of sporangia of unclear taxonomic affinity are known from the Roblín Member.

Presence of some of the plant genera has been disputed by Yurina *et al*. (2009).

4.3.2.1.3 Ichnofossil record

The Roblín Member contains the ichnogenera *Arenicolites*?, *Bifungites*, *Chondrites*?, *Gordia*, *Helminthopsis*, *Planolites*, *Treptichnus*, *Urohelminthoida*? and *Zoophycos*. Generally, ichnofossils are scarce in the unit (Mikuláš & Pek 1996).

Moreover, microbially induced sedimentary structures have been documented from sediments of the Roblín Member (Vodrážková *et al*. 2019).

4.3.2.1.4 Microfossil record

Lele (1972) has published finds of several acritarch and spore genera from the Srbsko Formation. The acritarchs are represented by *Leiosphaeridia*, *Cymatiosphaera, Micrhystridium*, *Veryhachium*; spores include *Ancyrospora*, *Aneurospora*, *Apiculiretusispora*, *Auroraspora, Biornatispora*, *Calyptosporites*, *Convolutispora*, *Dibolisporites*, *Leiotriletes*, *Perotriletes*?, *Punctatisporites*, *Retusotriletes, Rhabdosporites*, *Samariporites* and *Spinozonstriletes*. Furthermore, unspecified chitinozoans have also been described.

Dašková & Vacek (2009) have documented leiospheres together with miospore genera aff. *Geminispora*, aff. *Grandispora* and aff. *Samarisporites* and plant remains (nematoclasts) from the Roblín Member.

Yurina *et al*. (2009) have reported occurrence of the following spores: *Apiculiretusispora*, *Archaeozonotriletes*, *Calamospora*, *Chelinospora*, *Cymbosporites*, *Diatomozonotriletes*, *Dibolisporites*, *Geminospora Grandispora*, *Hystricosporites*, *Rhabdosporites*, *Samarisporites*, *Verrucosisporites*.

5. Methods

Twenty–two samples of fine-grained siliciclastic rocks from selected stratigraphic levels of the lower Paleozoic of the Barrandian area were processed following the 'low–manipulation HF extraction' method described by Butterfield & Harvey (2012). The surface of the rock samples was washed, mechanically cleaned (to minimalize the risk of contamination by Recent organic material, e.g. spores or fibres of fungi) and dried. Crushing of rock samples by hammer (which is commonly used to enlarge the reactive surface and thus make the dissolution quicker – see Paris 2006, Traverse 2007) was minimized to avoid potential destruction of SCFs (see Burzin 1989, Butterfield & Harvey 2012).

The rock fragments were weighted, put into a plastic container, and immersed into concentrated 40% hydrofluoric acid. After sufficiently long time for the sample to be dissolved (usually after two to five days) the residue was moved on plastic 30 or 54 µm sieve. The sample was repeatedly gently washed by water on the sieve to separate small particles and remove remaining acid (as the samples tend to be still significantly acid after the dissolution). Afterwards, the residue was moved to ethanol and stored in plastic beakers.

This method was used to minimize mechanical destruction of the fossils (as mentioned before in chapter *Small Carbonaceous Fossils (SCFs)*).

Some samples (HlTr–01, HlTr–02, Levín–01, Levín–02 and HLUB–A1, HLUB–B1 and several barren samples) were processed by Dr. Tom Harvey at the University of Leicester (UK). These samples were processed in a similar way, only after they had been dissolved in a dish, the residue was sieved on a sieve with mesh size 60 µm and the residues were stored in distilled water instead of ethanol.

The residues obtained were studied by optical microscopy. Objects were handpicked by pipette and mounted on cover glasses or fixed to SEM stubs.

6. Material and Results

6.1 Paseky Shale

6.1.1 Medalův mlýn

Three samples of green shale from the upper part of the Paseky Shale Member at the outcrop ‘Medalův mlýn’ (for its location see Chlupáč *et al*. 1995) were processed. No fossils were recovered. The absence of organic–walled fossils in samples from this locality has also been ascertained in previous research of the Paseky Shale (O. Fatka, personal communication).

6.1.2 Tok Hill

For description of the Tok Hill locality see Chlupáč *et al*. (1995). Re–Study of already existing slides (provided by O. Fatka) from samples processed by standard palynological maceration (using both hydrochloric and hydrofluoric acids) yielded the following results. Apart from filamentous microfossils and leiospheres, two specimens of tetrade–like objects were found. These are of size and morphology comparable to objects described as cryptospores by Strother (2016). Furthermore, spine–shaped objects were found.

6.1.3 Kočka Hill

Two samples of grey to green shale were dissolved; the samples came from the locality Kočka Hill (see Chlupáč *et al*. 1995). The residue contains a significant amount of only partially dissolved matrix. The extracted material yielded a specific microfossil assemblage; this consists mainly of filamentous fossils; co–occurring, but significantly less abundant are metazoan remains. Furthermore, one specimen of *Leiosphaeridia* was recovered (see Fig. 2).

Acritarchs *s.l.*

Only one specimen of *Leiosphaeridia* (Fig. 2A) was recovered. No acritarchs were found, possibly due to mesh size of the sieve (30 µm) utilized during processing being too large.

Filamentous microfossils

The most abundant microfossils present belong to various filamentous fossils, assigned here to the genera *Botuobia*, *Polytrichoides* and *Siphonophycus*. Comparable specimens have been interpreted as fragments of algae *Marpolia spissa* by Steiner & Fatka (1996).

Metazoan remains

Other organic–walled microfossils are sparse. Recovered elements include an articulated row of conical spines (Fig. 2M) and several individual spines.

6.2 Jince Formation

6.2.1 Vinice – Za Baborským

Four samples of silty shale (JS–V1 – JS–V4) from the lower part of the *Onymagnostus hybridus* Interval Zone were processed; the locality has been documented by Fatka & Kordule (1992) as 'Locality 19'. No fossils were recovered from samples JS–V1 and JS–V2 (probably due to methodological mistakes); samples JS–V3 and JS–V4 yielded various organic–walled microfossils, including individual acritarchs, filamentous fossils and small carbonaceous fossils (clusters of acritarchs and metazoan remains).

Acritarchs

Residues contained specimens of several genera: *Adara*, *Cymatiosphaera*, *Eliasum*, *Leiosphaeridia*, *Stictosphaeridium*? and *Timofeevia*.

It seems noteworthy, that accumulations of *Cymatiosphaera*, *Eliasum*, *Leiosphaeridia*, *Stictosphaeridium*? and *Timofeevia* are present (see Fig.4). These range from several specimens to massive accumulations of several tens of specimens. A significant part of the accumulations is monogeneric. Several tetrads were discovered in residues acquired using the low–manipulation method as well as on permanent slides containing microfossils extracted by standard palynological processing methods (provided by O.

Fatka). Isolated acritarch specimens are also present; however, their number was most probably strongly reduced due to application of the 30 μm sieve.

Filamentous fossils

Several filamentous microfossils were recovered (see Fig. 4).

Remains of metazoan affinity

One sample (JS–V3) provided three well–preserved sclerites belonging to *Wiwaxia*. The elements exhibit typical structures, including a thickened edge and longitudinally oriented ribs. The more complete sclerite corresponds to ventrolateral sclerites of *Wiwaxia*. All sclerites were partly damaged, probably due to diagenesis and laboratory processing.

Several other fragments of possible metazoan origin were extracted, but their affinity could not be established more precisely, because of a poor preservation.

6.2.2 Felbabka

A sample of siltstone came from an interval covering the upper levels of the *Hypagnosthus parvifrons* Interval Zone to the lower portions of the *Paradoxides* (*Paradoxides*) *paradoxissimus gracilis* Taxon–range Zone (locality Felbabka *sensu* Fatka *et al*. 2018). Fossils are rare in the residue; *Annulum*? and *Leiosphaeridia* were recovered.

6.3 Letná Formation

6.3.1 Zbraslav

One sample of dark silty shale (with abundant mica) from the locality Zbraslav (locality Praha 5 – Zbraslav *sensu* Mikuláš 1998) was processed. The section at Zbraslav consists of a succession of rhythmically changing sandstones and shales. The studied sample yielded various organic–walled microfossils, including acritarchs, cuticular fragments, chitinozoans and scolecodonts.

Acritarchs *s.l.*

Abundant acritarchs are present (see Fig. 7). The majority of these acritarchs belong to the genus *Veryhachium*. All recovered specimens of *Veryhachium* are triangular in outline. One specimen belonging to the genus *Ordovicidium* (Fig, 7A) and several large, but poorly preserved *Leiosphaeridia* were discovered.

Chitinozoans

Chitinozoans are relatively abundant in the studied residue. The following genera were discovered: ?*Belonechitina*, *Conochitina, Cyathochitina*, *Desmochitina*, *Euconochitina* and *Linochitina*. Two chains of chitinozoans were found, each consisting of two specimens of *Linochitina* (see Fig. 6).

Scolecodonts

The sample yielded closer undetermined scolecodonts.

Cuticular fragments

Fragments of organic sheets are abundant in the sample, one well preserved remain shows a set of parallel striations (Fig. 6B).

6.4 Kosov Formation

6.4.1 Levín

Samples from two localities were studied. The first of the studied localities is Levín, corresponding to the lowermost portion of the formation (see Štorch & Fatka 2006). Two samples of mudstone to siltstone, from the lowermost portion of the formation, were processed. The extracted residues contain acritarchs, chitinozoans, cuticular fragments and tubes as well as fossils of uncertain affinity (see Fig. 8).

Acritarchs *s.l.*

All recovered acritarchs were strongly altered and their wall surfaces were damaged.

Chitinozoans

The chitinozoans recovered are differentially preserved. Some specimens are well–preserved, while other are only fragmentary. Specimens belonging to several genera were recovered, including ?*Conochitina*, *Euconochitina* and ?*Spinachitina*.

Incertae sedis

A fragment of organic–walled fossil with polygonal texture was recovered (Fig. 8G). Unfortunately, the fragment is poorly preserved and doesn`t allow further analyse.

Additionally, two thin–walled tube–like objects, approximately 100 μm in length, were recovered.

6.4.2 Hlásná Třebáň

The second studied locality is located in Hlásná Třebáň (see Mikuláš 2019, p. 63). Organic–walled microfossils are relatively more abundant in samples taken from this locality, however, this finding has only a limited value as neither of the localities was sampled systematically. Two samples were studied.

Acritarchs *s.l.*

Most of the recovered acritarchs are poorly preserved. One dyad was obtained.

Chitinozoans

Chitinozoans from this sample are generally worse preserved than chitinozoans from the Levín samples. However, the variety of preservation is wide, including some well–preserved specimens. Specimens recovered belong to the genera *Conochitina, Cyathochitina* and ?*Euconochitina*.

Scolecodonts

The sample also contains closer undetermined scolecodonts.

Incertae sedis

As in the previous sample, a fragment of cuticle with polygonal units was discovered (Fig. 8F). It has approximately 100 μm in diameter. This specimen is significantly better preserved than the specimen from Levín sample. Its edges are clearly not original; it has been broken off a bigger piece. Similar objects have been reported by Vavrdová (1988) as fragments of potential terrestrial plants.

6.5 Daleje Shale

6.5.1 Pod Dračí Skálou

Two samples of silty shale with different abundance of plant material and shelly fossils (mainly tentaculites and brachiopods) were dissolved; the samples come from the locality

‘Pod Dračí skálou’ (see Budil *et al*. 2013). The locality corresponds to the middle to upper portion of the Daleje Shale.

Abundant acritarchs, prasinophytes, leiospheres, scolecodonts and shelly fossils were recovered (see Figs. 9, 10).

Acritarchs *s.l.* and prasinophytes

The most abundant components in the residues are prasinophytes (?*Tasmanites*) and *Leiosphaeridia*. Acritarchs are represented by *Navifusa*.

Chitinozoans

Chitinozoan genera *Ancyrochitina*, *Angochitina* and ?*Sphaerochitina* were obtained.

Scolecodonts

Some scolecodonts were recovered; they include paulinitids, polychaetaspids (?*Oenonites*) and putative tetraprionids.

Shelly Fossils

Although the HF extraction method is mainly utilized for extraction of organic–walled fossils, it allowed extraction of tentaculites (see Fig. 13), brachiopods and fragments of trilobite exoskeletons. Some of the recovered specimens do have surface ornamentation preserved. The fossils are transparent to translucent. Moreover, in the tentaculites, the inner volume can be distinguished from the surrounding shell.

6.6 Srbsko Formation

6.6.1 Hlubočepy

Four samples of siltstone (HLUB–A1, HLUB–B1, SS–ŽZ1, SS–ŽZ2) from the lower parts of the Roblín Member containing macroscopic plant debris were dissolved. The recovered fossils include chitinozoans, leiospheres, spores, scolecodonts and shelly fossils (Figs. 11–13).

Acritarchs *s.l.*

Poorly preserved specimens, were recovered; herein, they are assigned to ?*Leiosphaeridia*.

Chitinozoans

One poorly preserved specimen of chitinozoan affinity was recovered.

Spores

Most of the recovered spores were only poorly preserved. A significant portion of the spores is tentatively assigned to ?*Grandispora*, but there are probably several genera present.

Scolecodonts

Abundant fragments of scolecodonts were recovered. More complete specimens are rare, but present, nevertheless; however, they were not determined.

Incertae sedis

Several elements of suspected metazoan affinity were recovered; these include putative organic remains of a tentaculite (Fig. 12I; for comparison see Marshall & Tel'nova 2017), elements resembling arthropod cuticle (Figs. 12J,K) and an element of unknown affinity (Fig. 12H).

Shelly fossils

A poorly preserved fragment of tentaculite was recovered (Fig. 13I). The state of the fossil is comparable to the specimens recovered from the Daleje Shale.

6.6.2 Hostim

One sample of siltstone with plant remains was processed. The sample came from the lower portions of the Roblín Member; the outcrop is located southwest from Hostim (see Chlupáč 1958, p. 155). The residue contains generally poorly preserved plant debris. Leiospheres recovered are poorly preserved as well. No fossils of metazoan affinity (e.g. scolecodonts or chitinozoans) were recovered.

6.7 Fluoritised fossils

The residues recovered from samples of the Daleje Shale and the Srbsko Formation contain shelly fossils together with organic–walled fossils. The shelly fossils are represented mainly by tentaculites; in residues from the Daleje Shale samples, several brachiopods and fragments of trilobite exoskeletons are present as well.

These fossils are generally micro– to mesoscopic, ranging from several hundreds of microns to more than one millimetre in size. They are translucent to transparent, possibly allowing study of their internal structure. In this regard, these fossils are very similar to silicified microfossils. In some specimens, fine surface details are preserved.

Several recovered tentaculites were crushed into powder and analysed by the XR diffraction. The results (Fig. 13) correspond to a poorly crystalline fluorite (Goliáš personal communication). This could be explained by a quick reaction of the originally calcareous material with hydrofluoric acid utilized for dissolution of the rock samples.

7. Discussion

The main aim of this study was to test the applicability of the 'low–manipulation HF extraction' method on selected samples originating from the Barrandian area. The herein studied stratigraphic levels were selected based on their lithological character combined with previously published microfossil record. The nature and scope of this study only allowed a limited number of samples from each stratigraphic level to be studied.

7.1 Cambrian

The Cambrian samples originate from the Paseky Shale Member, which has yielded SCFs earlier (Fatka & Konzalová 1995), and the *Onymagnostus hybridus* Interval Zone of the Jince Formation, where abundant and well–preserved OWMs have been ascertained during previous research (e.g. Fatka 1989). Furthermore, a sample from the upper parts of the Jince Formation was processed. For the stratigraphic position of the individual units see Fig. 1.

Generally, the samples yielded fossil assemblages comparable to those reported previously. However, the 'low–manipulation HF extraction' method further provided tetrads (cryptospores *sensu* Strother & Beck 2000) and small carbonaceous fossils, namely spine–shaped elements, *Wiwaxia* sclerites and various acritarch clusters; recovered fossils are figured on Figs. 2,3,4.

Acritarch clusters and cryptospores

Acritarchs occurring in clusters have been known for a long time and clustering has been observed in a wide variety of acritarchs (discussion e.g. in Downie 1973).

No recurring patterns in size or general shape were noticed in clusters recovered from the Jince Formation. The number of individual elements forming a cluster also varies strongly, from several to tenths of specimen. However, the fact that a significant portion of the clusters are monogeneric, and that multiple genera co–occur in such clusters in the same sample suggests, that the clusters are not random accumulations.

Furthermore, the Cambrian samples from the Paseky Shale and the Jince Formation yielded tetrads, recovered by both 'standard' and 'low–manipulation' methods. Comparable elements of Cambrian age have been described by Strother & Beck (2000) as cryptospores *s.l.* and interpreted as objects of terrestrial origin, but not necessarily related to embryophytes.

Ceratophyton

Several specimens of spine–shaped elements (traditionally assigned to the acritarch genus *Ceratophyton*) were discovered during examination of material from the Paseky Shale (both already existing slides and newly recovered residues). These elements include narrow, straight to slightly curved elements and an articulated set of short spines with relatively wide bases. Unfortunately, only few elements were recovered, and consequently only limited conclusions can be proposed. Moreover, all recovered elements are partly damaged and do not exhibit all features necessary for an unambiguous determination.

The first report on spine–shaped fossils assigned to the genus *Ceratophyton* from the studied stratigraphic level has been published by Fatka & Konzalová (1995), who have recognized the metazoan affinity of some curved elements and interpreted such elements as appendages of Copepods based on similarities with sub–recent material from Indonesia (for discussion see Fatka & Konzalová 1995).

Nagovitsin (2011) and Slater *et al*. (2017, 2018a) have re–interpreted similar elements recovered from the Cambrian of Siberia and Baltica, respectively, as organically preserved protoconodonts; Slater *et al*. (2018a) have assigned such elements to the protoconodont genus *Protohertzina*. Similar elements have further been reported by Slater *et al*. (2018b) and Slater & Willman (2019).

One of the specimens (Fig. 2L) resembles material published by Slater *et al*. (2018a). Therefore, these elements are herein tentatively assigned to protoconodonts. Another element (Fig. 2N) is even more problematic, it could either belong to chaetognath, or a further unspecified scalidophoran.

Of special interest is the best–preserved specimen represented by a row of four connected conical *Ceratophyton*–like elements. It resembles mouth parts of various bilaterian metazoans (see discussion in Slater *et al*. 2017), possibly chaetognath posterior teeth (Harvey, personal communication; for recent analogue see Szaniawski 2002, Fig. 7B).

As presented in the description of the Paseky Shale (Chapter 3), the fossil record is not very diverse, which is a result of specific environment. Therefore, any contribution to the actual knowledge of fossil record is important and contributes to a better understanding of early Paleozoic ecosystems of restricted marine environments.

Wiwaxia

Sclerites of *Wiwaxia* were recovered from the sample coming from the *Onymagnostus hybridus* Interval Zone (see Results).

The fossil record of the genus *Wiwaxia* covers a significant part of the Series 2 of Cambrian and of Miaolingian. Furthermore, its occurrence has been reported from the Early Ordovician of Morocco (Van Roy *et al*. 2015). Two possible wiwaxiid elements have even been described from the Middle Ordovician of Portugal (Kimmig *et al*. 2019). The record of *Wiwaxia* consists of fossils preserved as body–fossils on surface of bedding plane (both individual disarticulated sclerites and articulated scleritomes) and of microfossils (mainly discovered as SCFs). Isolated sclerites of *Wiwaxia* have also been described from inside cololites (Vannier 2012).

Macrofossil record of *Wiwaxia*

Specimens of *Wiwaxia* on bedding planes have been reported from Laurentia (Matthew 1899, Walcott 1910, Conway Morris 1985, Conway Morris & Robison 1988, Conway Morris *et al*. 2015), European and Asian peri–Gondwana (China, Zhao *et al*. 1994, Sun *et al*. 2014, Yang *et al*. 2014, Zhao *et al*. 2015, Zhang *et al*. 2015; Czech Republic, Fatka *et al*. 2011b and possibly Portugal, Kimmig *et al*. 2019), Gondwana (Australia, Southgate & Shergold 1991, Porter 2004; Morroco, Van Roy *et al*. 2015) and Siberia (Russia, Ivantsov *et al*. 2005a,b).

Microfossil record of *Wiwaxia*

As has been noted higher, the majority of published microfossil remains of *Wiwaxia* is represented by organic–walled fossils. The SCF record of *Wiwaxia* consists of fossils originating from several stratigraphic levels in different areas of the world. *Wiwaxia* has been reported from Baltica (Slater *et al*. 2017), eastern Gondwana (Smith *et al*. 2016), European and Asian peri–Gondwana (China, Harvey *et al*. 2012a; Spain, Palacios *et al*. 2014) and Laurentia (Butterfield 1990, Butterfield & Harvey 2012a, Harvey & Butterfield

2011, Harvey *et al*. 2012b, Pedder 2012). The finds of *Wiwaxia* are represented mainly by sclerites and less often by fragments of feeding apparatuses as well (e.g. Smith *et al*. 2016).

Porter (2004) published secondarily phosphatized isolated sclerites from Gondwana (Australia).

The palaeogeographic signal of *Wiwaxia* has been discussed recently. It has been proposed that the occurrence of the taxon is an indicator of tropic to sub–tropic environment (Fatka *et al*. 2011b). However, since then this interpretation has been disputed based on material from Llanos Basin, Colombia, which has been interpreted to be located in high palaeolatitudes during Cambrian (Smith *et al*. 2016). Moreover, wiwaxiids have also been described from the Fezouata Lagerstätte (see macrofossil record of *Wiwaxia*), which was positioned in high palaeolatitudes during Early Ordovician (Van Roy *et al*. 2015, Martin *et al*. 2016). Generally, sediments from shallow–water environments do mainly contain juvenile specimens, while in deep–water sediments adult specimens are more common (Zhang *et al*. 2015).

Based on articulated macrofossils, five species of *Wiwaxia* have been established so far: *Wiwaxia corrugata* Matthew, 1899, *Wiwaxia taijaigensis* Zhao, Qian et Li, 1994 (although it has been proposed that *W. taijaigensis* may be a junior synonym of *W. corrugata* by Sun *et al*. 2014), *Wiwaxia foliosa* Yang, Smith, Lan, Hou et Zhang 2014, *Wiwaxia papilio* Zhang, Smith et Shu, 2015 and *Wiwaxia herka* Conway Morris, Selden, Gunther, Jamison *et* Robison, 2015. Furthermore, possible existence of other species has been proposed based on isolated sclerites (e.g. Butterfield 1994, Porter *et al*. 2004).

The phylogenetic position of *Wiwaxia* has been debated for a long time. Generally, it is considered to be closely related to the coeval genus *Odontogriphus* (e.g. Butterfield 2006, Caron *et al*. 2006, Smith 2014, Yang *et al*. 2014) and possibly some other Ediacaran/Cambrian taxa (see Caron *et al*. 2006, Smith 2014). Walcott (1910) has proposed relationship of *Wiwaxia* to *Aphroditidae* or *Polynoidae*. More recently, *Wiwaxia* has been referenced as being either a stem–group Lophotrochozoan with a possible relationship to annelids (e.g. Butterfield 2006, Han *et al*. 2019) or a total–group mollusc (e.g. Caron *et al*. 2006, Smith 2014).

The recovered sclerites differ significantly from elements described by Fatka *et al*. (2011b) both in size and morphology.

The presence of the emblematic taxon *Wiwaxia* is another example of the growing evidence of presence of Burgess Shale–type taxa in the Jince Formation (see Chlupáč & Kordule 2002, Fatka *et al*. 2004, Mikuláš *et al*. 2012).

The results obtained from the Cambrian samples contribute to the knowledge of the studied levels and are very promising as results of a pilot study, on which a further, more focused, and thorough research will be based.

7.2 Ordovician

Two stratigraphic levels were sampled: (a) the Letná Formation and (b) the Kosov Formation (see Fig. 1)

The residues from Cambrian and Ordovician samples are markedly different. The sample from the Letná Formation yielded a nearly monogeneric acritarch assemblage, associated with chitinozoans, scolecodonts and various specimens classified as *incertae sedis*. Although the method is not primarily adapted for the extraction of acritarchs, one specimen of the genus *Ordovicidium* was recovered; the genus has not been previously reported from the Letná Formation. Interesting is the discovery of abundant cuticular fragments, which have not been previously described from this stratigraphic level. This is probably a result of the different methodology. One of the undetermined specimens bears a distinct parallel striation.

The fossils recovered from the younger Kosov Formation do generally correspond to the earlier described material.

7.3 Devonian

The studied samples come from two stratigraphic levels: (a) the Daleje Shale and (b) the Roblín Member (see Fig. 1).

The study of Devonian samples (mainly of the Daleje Shale) provided results that are significant primarily from the methodological point of view; these are discussed below. The recovered fossils do generally not extend the earlier published records. From the

Roblín Member, scolecodonts have not been reported; however, this is probably a result of studies focusing mainly on spores; furthermore, the recovered scolecodonts are generally poorly preserved. Elements of possible metazoan affinity were recovered, but more specimens will be necessary for a proper classification.

Originally calcareous fossils were recovered from the Devonian samples; this was reached *via* the process of fluoritisation.

Fluoritisation

The extraction of shelly fossils by means of palynological processing has not been widely applied; generally, it has been discussed in groups of phosphatic and calcareous original composition.

Occurrence of originally phosphatic elements, like conodonts, has been reported from rock samples (mainly cherts) treated by hydrofluoric acid (e.g. Orchard 1987, Etherington & Austin 1993).

Remains of originally calcareous fossils that had undergone HF treatment have been so far documented in several papers. The procedure has been described by Grayson (1956, p. 77) as: ”molecule–by–molecule replacement of the carbonate by the fluoride ion without any alteration of the gross structure of the object replaced“.

While the “standard” palynological maceration methods, involving treatment with the hydrochloric acid, do usually dissolve calcareous fossils (see e.g. Jarochowska et al. 2013), it has been demonstrated that HF treatment could be utilized for extraction of originally calcareous fossils (e.g. Wetzel 1921, Grayson 1956, Upshaw *et al*. 1957, Stancliffe & Matsuoka 1991). It has also been utilized to make the fossils translucent and thus easier to study (e.g. Stancliffe & Matsuoka 1991) or for cleaning of fossils from the surrounding matrix (e.g. Carini 1962). For the first time, this method of processing of calcareous microfossils has been reported nearly one hundred years ago (Wetzel 1921). Since, it has been successfully applied to extract and/or process a wide variety of fossil groups, including nannoplankton (Bramlette & Sullivan 1961), foraminiferans (e.g. Jenkins 1960), bivalves (e.g. Grayson 1956), ostracods (Sohn 1956, Adamczak 1961), brachiopods (Cookson & Singleton 1954), bryozoans (Cookson & Singleton 1954), crinoids (Sevastopulo & Keegan 1980) or holothurians (Carini 1962). The method has also been utilized for petrological studies (Tasch 1959, Glover 1978). It has even been proposed to be used as a way to prepare illustrative material for micropalaeontology students (Upshaw *et al*. 1957) Nevertheless, it seems to be rather sparsely utilized and even several–times "rediscovered" by individual authors (e.g. Grayson 1956, Sevastopulo & Keegan 1980, Stancliffe & Matsuoka 1991).

The potential for extraction of fossils by this method is possibly influenced by differences in structure, mineralogy, chemical composition and/or taphonomic pathway of diverse fossil groups from rocks of various diagenetic history. The concentration of the hydrofluoric acid can also be an important factor (Upshaw *et al*. 1957).

The application of HF treatment for extraction of calcareous fossils is, based on the papers related to the topic, utilized rather marginally, even though it is known for a significant period of time (Wetzel 1921).

This study represents the first application of the 'low–manipulation HF extraction' method in the Barrandian area. The study provides a further proof that the method can produce novel results even from stratigraphic levels that have been extensively examined before. The approach focusing on minimalizing the damage inflicted to fossils has a lot of potential for extending our knowledge about the fossil record. In the case of this pilot study, previously unknown fossils were recovered from several levels of the Palaeozoic of the Barrandian area, even with a limited number of samples. While there definitely are more effective methods for recovery of recalcitrant microfossils (such as many acritarchs, chitinozoans or spores), and while exceptionally preserved microfossils are restricted to only some stratigraphic levels (for discussion see Harvey & Pedder 2013), the 'low–manipulation HF extraction' method has a great value as a useful tool for reduction of the methodologically–induced bias. This quality is further enhanced by the possibility for extraction of some originally calcareous fossils, which are usually dissolved during more widely utilized HCl–HF–HCl treatment

8. Summary

The aim of the presented pilot study was to test the applicability of the 'low–manipulation HF extraction' method in six selected stratigraphic levels of the Barrandian area, with the goal to extract small carbonaceous fossils. The study provided new data on fossil record in the studied levels and methodology. The major novel outcomes can be summarized as:

Palaeobiology:

1) Sclerites of the iconic genus *Wiwaxia* and clusters of the acritarch genera *Cymatiosphaera*, *Eliasum*, *Leiosphaeridia*, and ?*Stictosphaeridium* were extracted from sample of the *Onymagnostus hybridus* Interval Zone for the first time. The wiwaxiid sclerites described herein represent the second occurrence of this genus in the Barrandian area and the fourth occurrence in Cambrian of the European peri–Gondwana.

2) Elements tentatively assigned to Chaetognatha (and other with possible scalidophoran affinity) were recovered from a sample of the Cambrian Paseky Shale.
3) Tetrade–like objects were discovered in residues of Paseky Shale and Jince Formation.
4) Abundant cuticles of putative metazoan affinity were recovered in the Letná Formation for the first time. One specimen of the *Ordovicidium* was recovered.

Methodology:

1) The 'low–manipulation HF extraction' method can be utilized for extraction of some calcareous fossils (e.g. brachiopods, tentaculites and trilobite exoskeletons), together with "commonly studied" organic–walled microfossils (e.g. acritarchs, chitinozoans, scolecodonts and spores) and more delicate objects (e.g. *Wiwaxia* sclerites, protoconodonts and accumulations of numerous acritarchs).
2) The 'low–manipulation HF extraction' method provides a quick and effective way to extract various microscopic and mesoscopic fossils from siliciclastic rocks. The downsides (in comparison to more widely utilized methods of palynological extraction) are a higher risk of secondary minerals (produced during the extraction

process) covering the fossils, and a possibly more time–consuming hand–picking of the fossils from the recovered residue.

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Fig. 1 – List of localities

1 - Medalův Mlýn

2 - Tok Hill

3 - Kočka Hill

4 - Vinice – Za Baborským

5 - Felbabka

6 - Zbraslav

7 - Levín

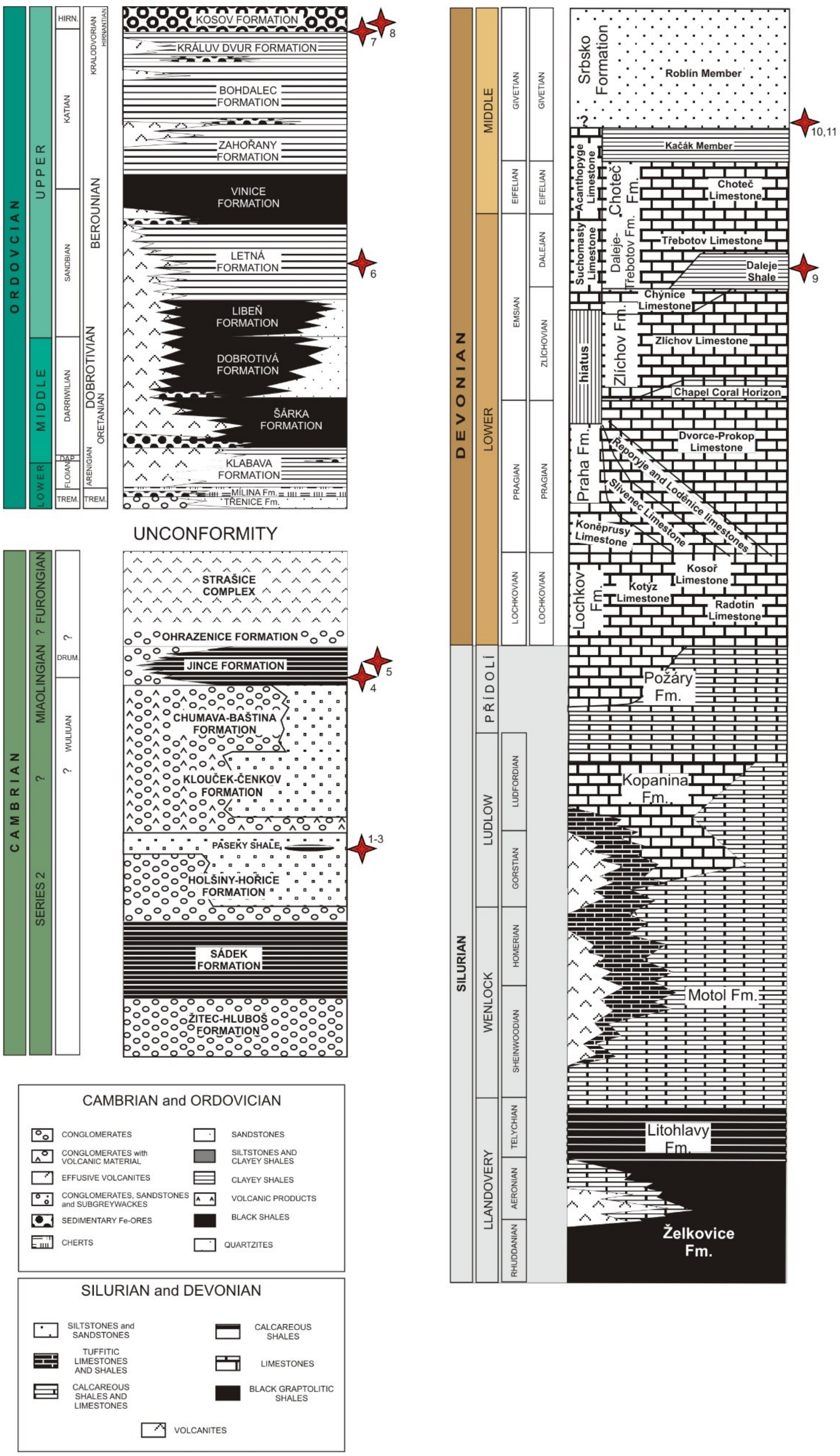
8 - Hlásná Třebáň

9 - Pod Dračí skálou

10 - Hlubočepy

11 - Hostim

The figure is based on Fatka et al. (2009, Fig.2), and further modified after, Budil et al. (2013), Gutiérrez–Marco et al. (2017), and Fatka & Valent (2019).



ORDOVICIAN
LOWER
MIDDLE
UPPER
TREM.
FLOIAN
DAP.
DARRIWILIAN
SANDBIAN
KATIAN
HIRN.
ARENIGIAN
ORETANIAN
DOBROTIVIAN
BEROUNIAN
KRALODVORIAN
HIRNANTIAN
KOSOV FORMATION
KRÁLUV DVUR FORMATION
BOHDALEC FORMATION
ZAHOŘANY FORMATION
VINICE FORMATION
LETNÁ FORMATION
LIBEŇ FORMATION
DOBROTIVÁ FORMATION
ŠÁRKA FORMATION
KLABAVA FORMATION
MÍLINA Fm.
TŘENICE Fm.
UNCONFORMITY
CAMBRIAN
SERIES 2
MIAOLINGIAN
FURONGIAN
WULIUAN
DRUM.
STRAŠICE COMPLEX
OHRAZENICE FORMATION
JINCE FORMATION
CHUMAVA-BAŠTINA FORMATION
KLOUČEK-ČENKOV FORMATION
PASEKY SHALE
HOLŠINY-HOŘICE FORMATION
SÁDEK FORMATION
ŽITEC-HLUBOŠ FORMATION
1-3
4
5
6
7
8
9
10,11
CAMBRIAN and ORDOVICIAN
CONGLOMERATES
CONGLOMERATES with VOLCANIC MATERIAL
EFFUSIVE VOLCANITES
CONGLOMERATES, SANDSTONES and SUBGREYWACKES
SEDIMENTARY Fe-ORES
CHERTS
SANDSTONES
SILTSTONES AND CLAYEY SHALES
CLAYEY SHALES
VOLCANIC PRODUCTS
BLACK SHALES
QUARTZITES
SILURIAN and DEVONIAN
SILTSTONES and SANDSTONES
TUFFITIC LIMESTONES AND SHALES
CALCAREOUS SHALES AND LIMESTONES
CALCAREOUS SHALES
LIMESTONES
BLACK GRAPTOLITIC SHALES
VOLCANITES
DEVONIAN
LOWER
MIDDLE
LOCHKOVIAN
PRAGIAN
EMSIAN
ZLÍCHOVIAN
DALEJAN
EIFELIAN
GIVETIAN
SILURIAN
LLANDOVERY
WENLOCK
LUDLOW
PŘÍDOLÍ
RHUDDANIAN
AERONIAN
TELYCHIAN
SHEINWOODIAN
HOMERIAN
GORSTIAN
LUDFORDIAN
Srbsko Formation
Roblín Member
Kačák Member
Acanthopyge Limestone
Choteč Fm.
Choteč Limestone
Suchomasty Limestone
Daleje-Třebotov Fm.
Třebotov Limestone
Daleje Shale
Chýnice Limestone
hiatus
Zlíchov Fm.
Zlíchov Limestone
Chapel Coral Horizon
Praha Fm.
Dvorce-Prokop Limestone
Řeporyje and Loděnice limestones
Slivenec Limestone
Koněprusy Limestone
Lochkov Fm.
Kotýs Limestone
Kosoř Limestone
Radotín Limestone
Požáry Fm.
Kopanina Fm.
Motol Fm.
Litohlavy Fm.
Želkovice Fm.

Fig. 2

Organic-walled microfossils of the Paseky Shale (Stage 4?, Cambrian), locality Kočka Hill.

A - *Leiosphaeridia* sp. - slide PB–K2c, EF: J.43–2.

B - *Siphonophycus* sp. - slide PB–K2b, EF: H.48–1.

C - *Polytrichoides* sp. - slide PB–K2a, EF: K.37–1.

D - ?*Siphonophycus* sp. - slide PB–K2b, EF: E.48–3.

E–H - *Polytrichoides* sp.
E - slide PB–K2a, EF: K.37–1.
F - slide PB–K2a, EF: H.41–4.
G - slide PB–K2a, EF: J.36–3.
H - slide PB–K2b, EF: J.33–1.

I–K - *Botuobia* sp.
I - slide PB–K2a, EF: L.42–2.
J - slide PB–K2c, EF: U.30–2.
K - slide PB–K2c, EF: G.38–3.

L - putative protoconodont superimposed on organic sheet - slide PB–K2a, EF: X.32–2.

M - row of conical *Ceratophyton*–like elements - slide PB–K2a, EF: K.40–1.

N - *Ceratophyton*–like element - slide PB–K2b, EF: J.33–4.

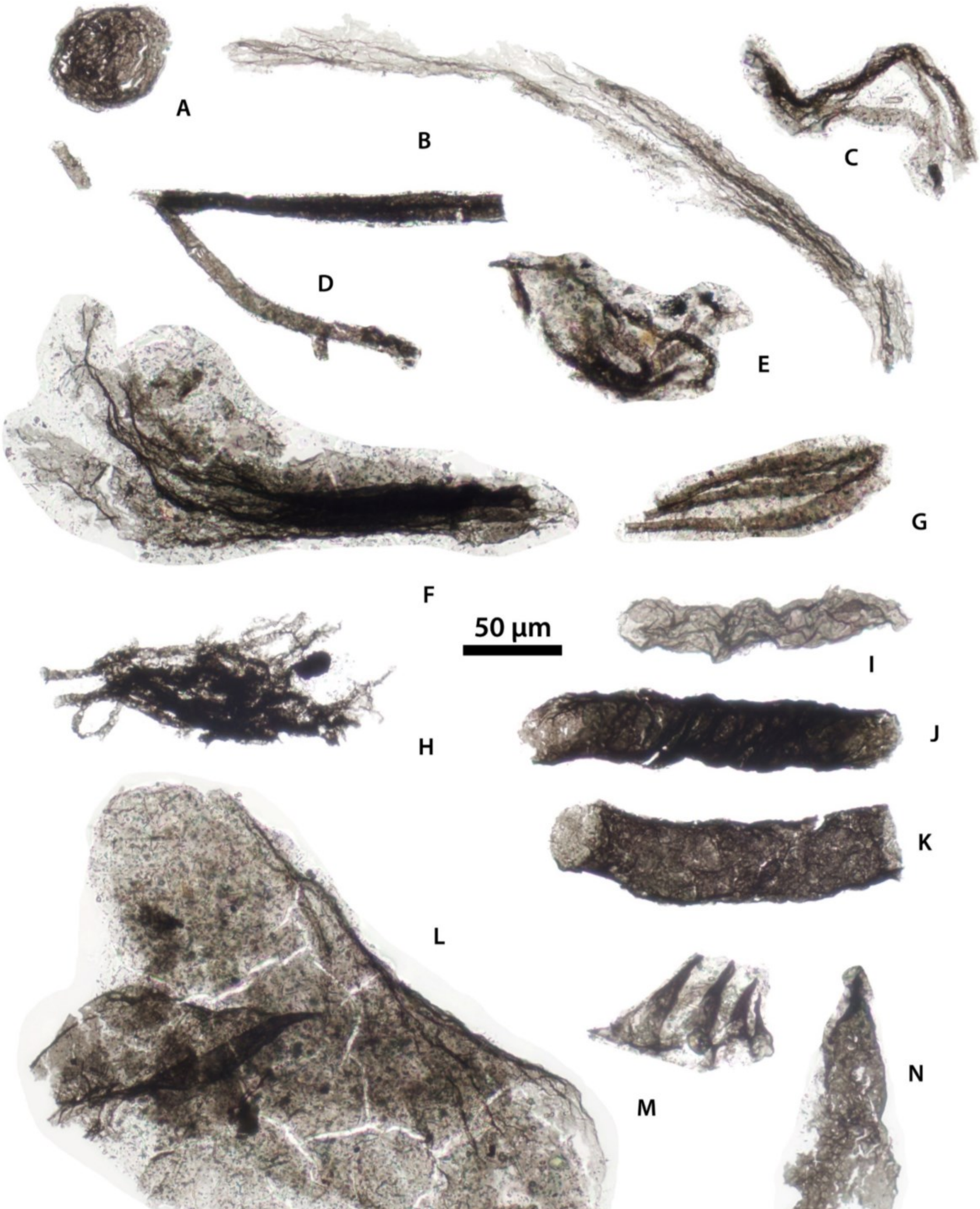

A
B
C
D
E
F
G
50 µm
H
I
J
K
L
M
N

Fig. 3

Wiwaxiid sclerites of the Jince Formation (Drumian, Cambrian), locality Vinice – Za Baborským.

A - damaged sclerite of ?*Wiwaxia* - slide JS–V3d, EF: K.39–2.

B - sclerite of *Wiwaxia* sp. - slide JS–V3d, EF: D.34–4.

C - ventrolateral sclerite of *Wiwaxia* sp., slide JS–V3b, EF: H.48–2.

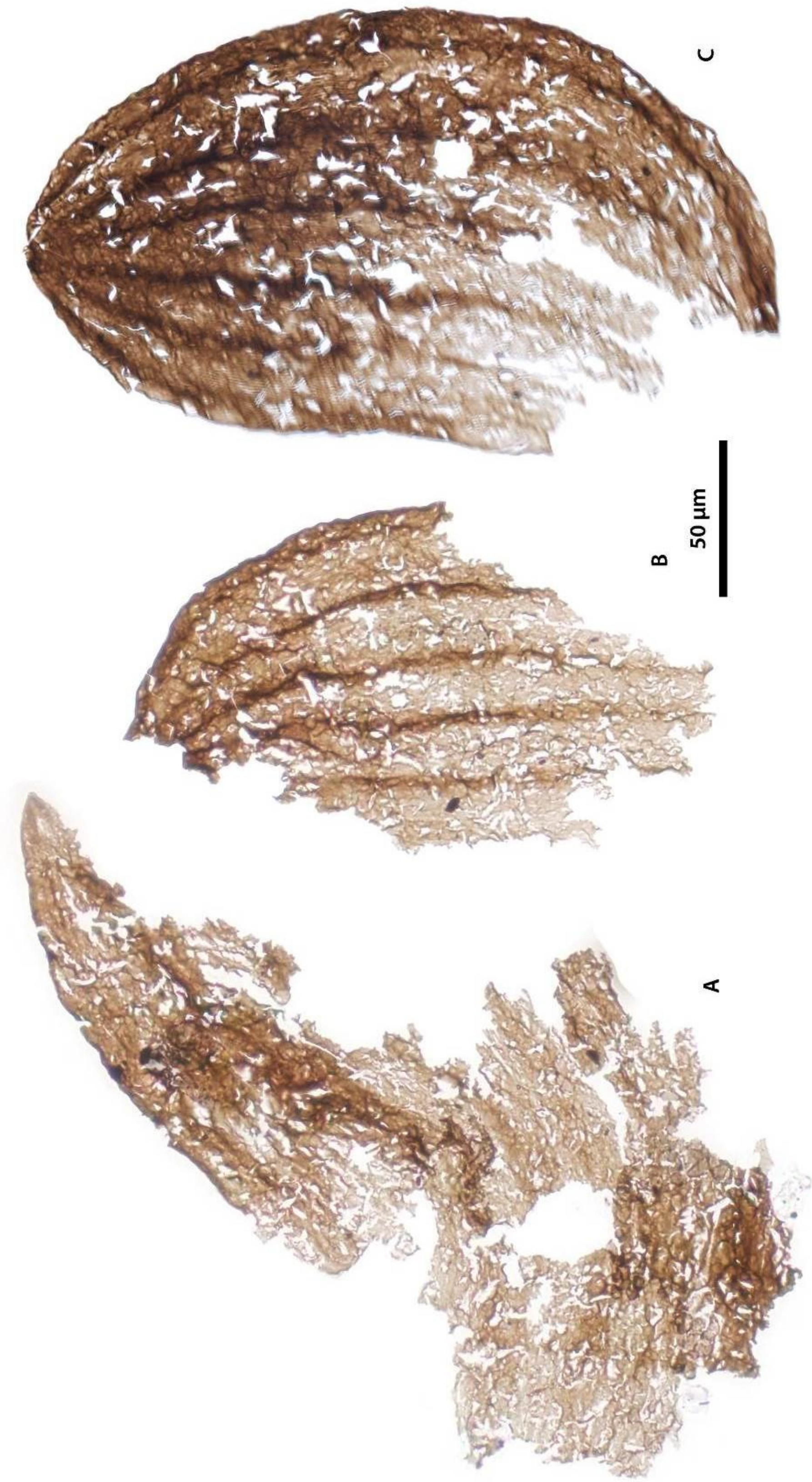

C
B
50 µm
A

Fig. 4

Organic-walled microfossils of the Jince Formation (Drumian, Cambrian), locality Za Baborským.

A - cluster of *Timofeevia* sp. - slide JS–V3f, EF: M.43–1.

B–C - tetrads.
B - slide JS–V3e, EF: K.46–1.
C - slide JS–V4a, EF: B.60–2.

D - cluster of *Cymatiosphaera* sp. - slide JS–V4b, EF: S.44–4.

E - cluster containing ?*Cymatiosphaera* and ?*Stictosphaeridium* - slide JS–V3e, EF: L.45–4.

F - cluster of *Cymatiosphaera sp.* - slide JS–V4a, EF: H.52–1.

G - tetrad - slide JS–V3b, EF: T.36–3.

H - cluster of *Eliasum* sp. - slide JS–V4b, EF: L.45–4.

I - filamentous fossil - slide JS–V3e, EF: P.40–4.

J - massive cluster of ?*Leiosphaeridia* sp. - slide JS–V4b, EF: F.46–3.

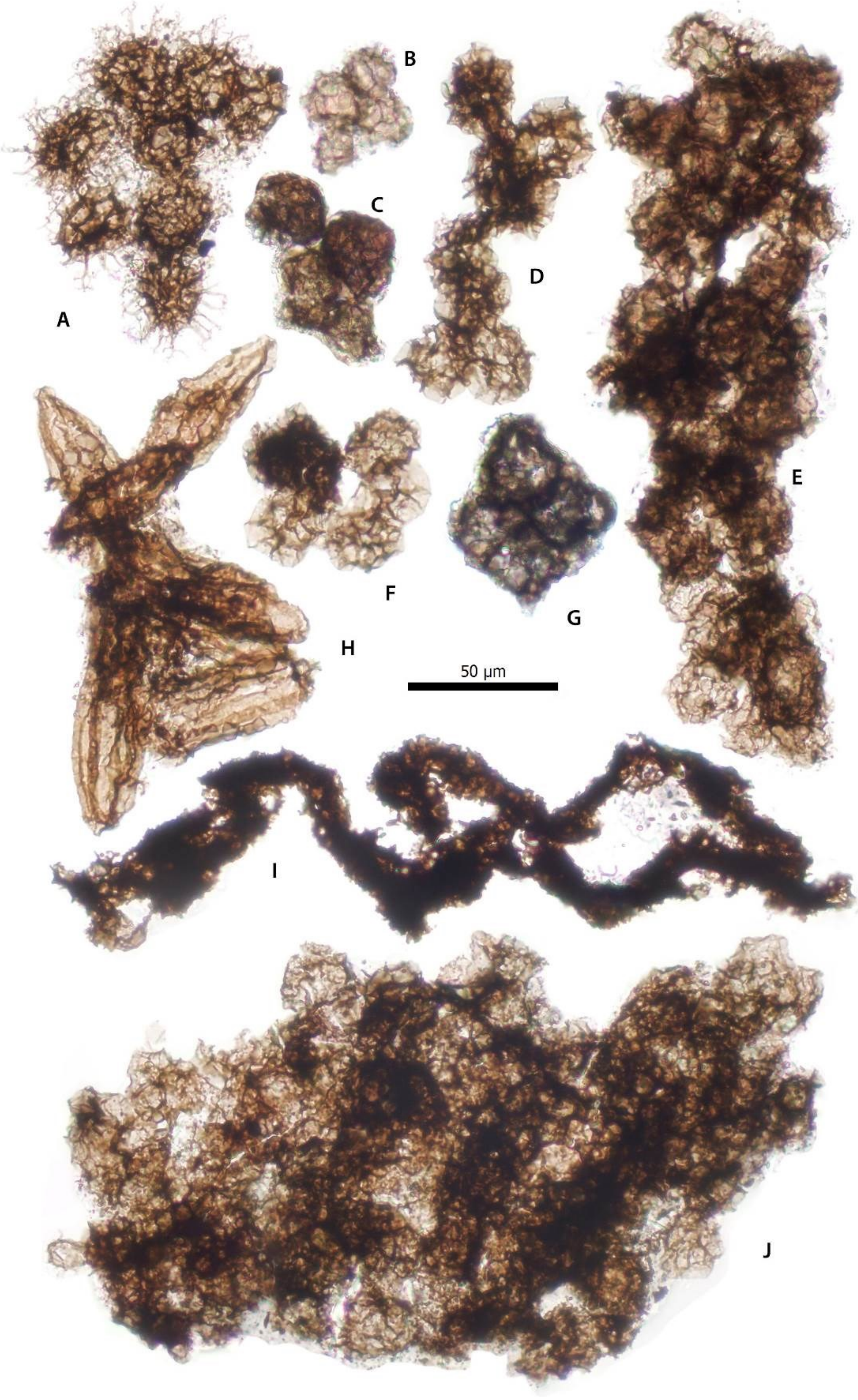

A
B
C
D
E
F
G
H
50 µm
I
J

Fig. 5

Organic-walled microfossils of the Jince Formation (Drumian, Cambrian), localities Za Baborským (A–X, AA–AC) and Felbabka (Y–Z).

A–B - *Timofeevia* sp.
A - slide JS–V3a, EF: S.30–4.
B - slide JS–V3a, EF: M.34–4.
C - slide JS–V3a, EF: L.42–1.
D - slide JS–V3f, EF: L.35–4.
E - slide JS–V4a, EF: S.50–3.

F–J - *Adara* sp.
F - slide JS–V3a, EF: V.30–1.
G - slide JS–V3a, EF: V.33–1.
H - slide JS–V3f, EF: W.45–1.
I - slide JS–V3f, EF: U.48–2.
J - slide JS–V3f, EF: W.45–1.

K–O - *Cymatiosphaera* sp.
K - slide JS–V3a, EF: H.33–3.
L - slide JS–V3A, EF: W.36–2.
M - slide JS–V3e, EF: E.34–2.
N - slide JS–V3c, EF: U.42–4.
O - slide JS–V3d, EF: Q.41–3.

P–R - *Eliasum* sp.
P - slide JS–V4a, EF: A.52–4.
Q - slide JS–V4b, EF: K.30–2.
R - slide JS–V4a, EF: S.51.

S - ?*Stictosphaeridium* sp. - slide JS–V3a, EF: S.46–4.

T–U - *Eliasum* sp.
T - slide JS–V4a, EF: R.43–4.
U - slide JS–V4b, EF: F.31–1.

V - ?*Leiosphaeridia* sp. - slide JS–V3c, EF: W.47–4.

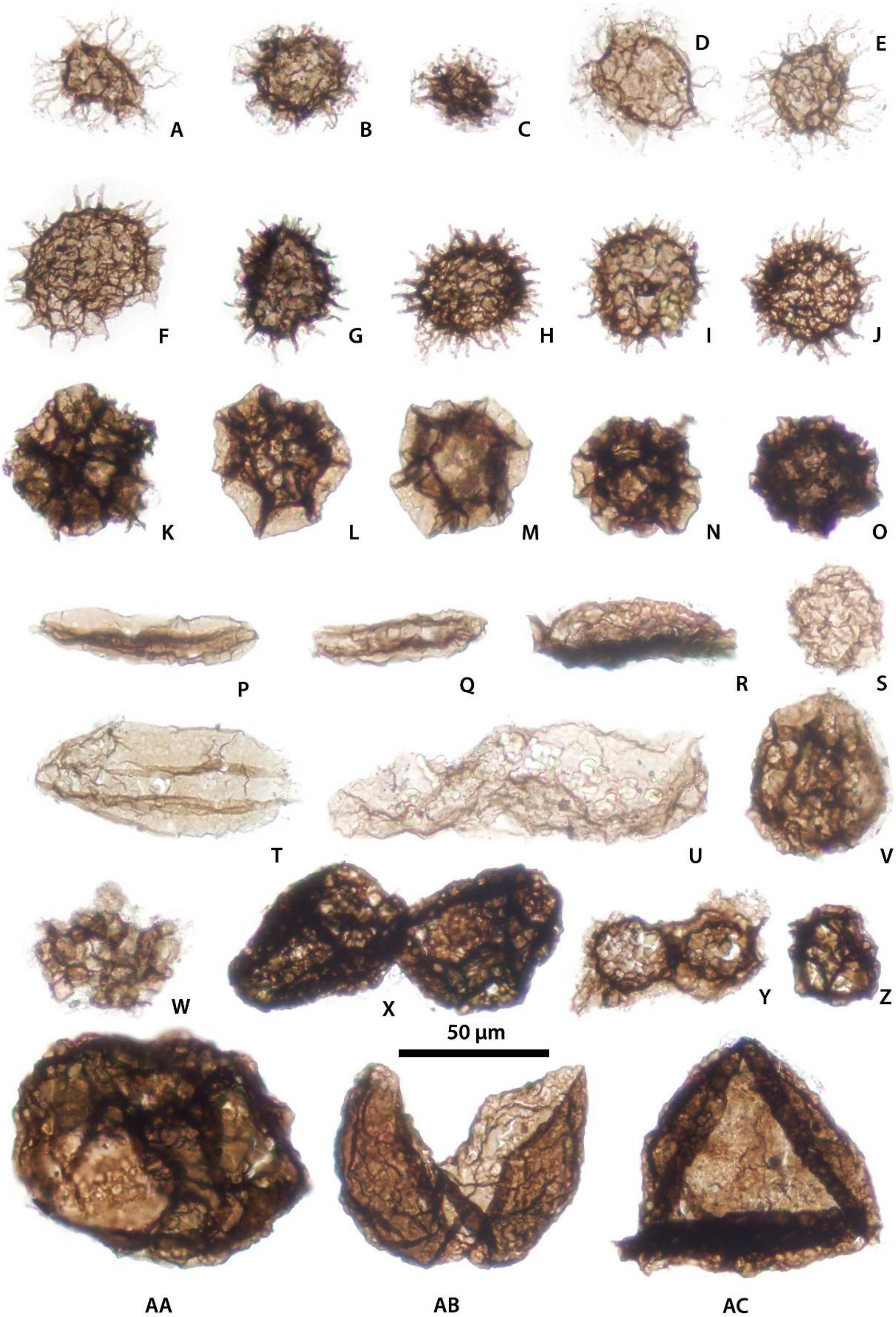
W - cluster of small sphaerical elements - slide JS–V4b, EF: L.30–2.

X - dyad - slide JS–V3a, EF: V.29–3.

Y - poorly preserved pair of ?*Annulum* sp. - slide JS–R3a, EF: P.42–2.

Z - *Leiosphaeridia* sp. - slide JS–R3a, EF: R.48–3.

AA–AC - ?*Leiosphaeridia* sp.
AA - slide JS–V3c, EF: J.28-2.
AB - slide JS–V3d, EF: O.32–1.
AC - slide JS–V3e, EF: K.32-4.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P
Q
R
S
T
U
V
W
X
Y
Z
50 µm
AA
AB
AC

Fig. 6

Organic–walled microfossils of the Letná Formation (Sandbian, Ordovician), locality Zbraslav.

A–E - cuticular fragments.
A - slide ZW3a, EF: T.44–4.
B - slide ZW3c, EF: M.34–2.
C - slide ZW3c, EF: L.43.
D - slide ZW3b, EF: L.37–4.
E - slide ZW3b, EF: C.34–1.

F–H - undetermined fossils.
F - slide ZW3b, EF: P.47–1.
G - slide ZW3a, EF: G.44–2.
H - slide ZW3c, EF: K.39–4.

I–K - undetermined scolecodonts.
I - slide ZW3b, EF: S.48–4.
J - slide ZW3b, EF: M.31–2.
K - slide ZW3b, EF: S.36–2.

L - ?*Belonechitina* sp. - slide ZW3b, EF: F.32–3

M - *Desmochitina* sp. - slide ZW3b, EF: F.32–1

N - *Cyathochitina* sp. - slide ZW3b, EF: R.40–4

O - *Conochitina* sp. - slide ZW3b, EF: C.42–4

P - chain of *Linochitina* sp. - slide ZW3b, EF: N.50–4


A
B
F
C
D
E
G
H
50 µm
I
J
K
N
O
P
M
L

Fig. 7

Organic–walled microfossils of the Letná Formation (Sandbian, Ordovician), locality Zbraslav.

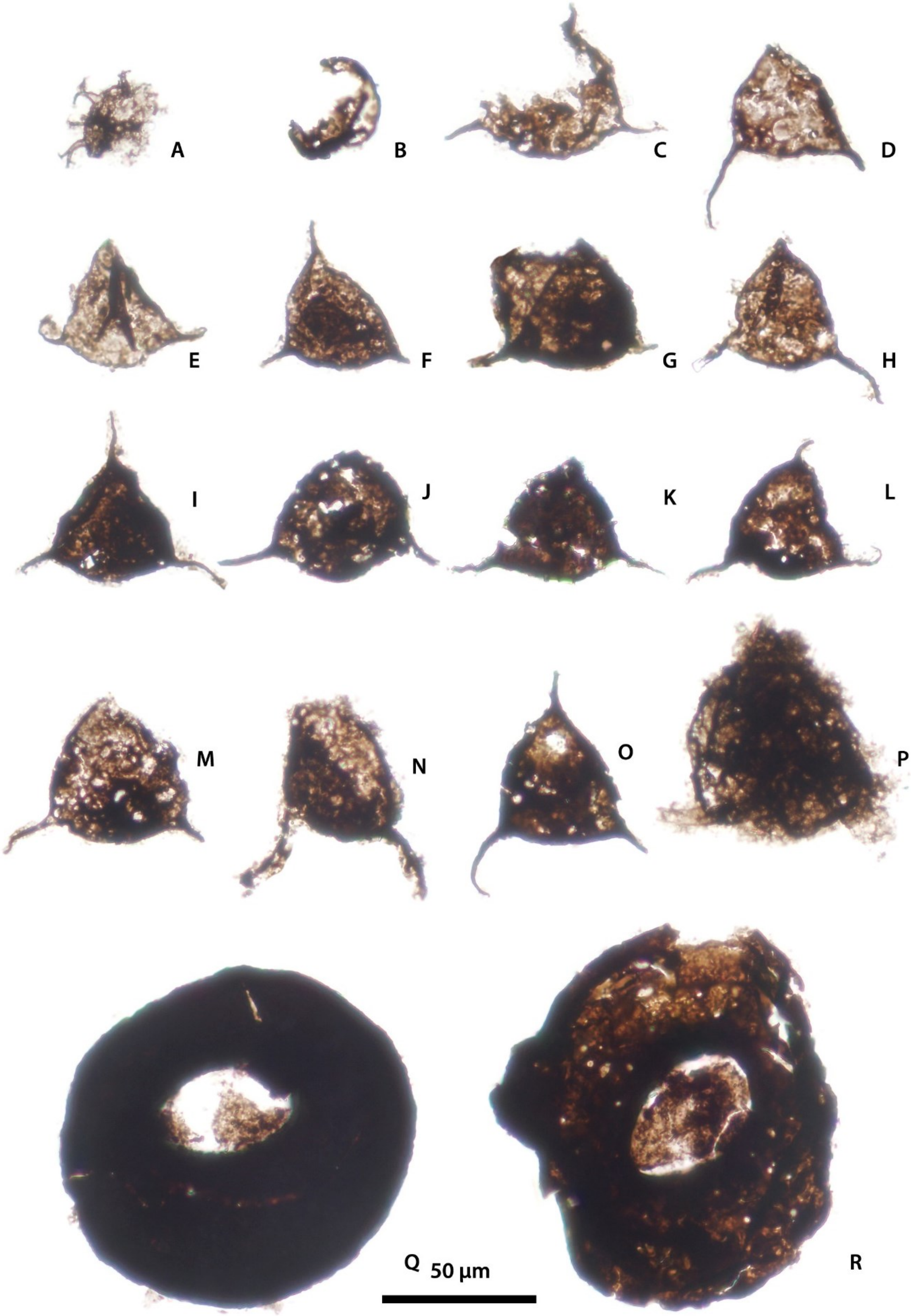
A - *Ordovicidium* sp. - slide ZW3c, EF: H.38–4.

B - undetermined acritarch - slide ZW3a, EF: S.37–1.

C–P - *Veryhachium* sp.
C - slide ZW3c, EF: M.43–3.
D - slide ZW3c, EF: S.43–4.
E - slide ZW3b, EF J.44–3.
F - slide ZW3c, EF: R.44–1.
G - slide ZW3b, EF: K.29–2.
H - slide ZW3b, EF X.44–4.
I - slide ZW3c, EF: Q.35–2.
J - slide ZW3c, EF: P.32–4.
K - slide ZW3b, EF: V.31–2.
L - slide ZW3a, EF: E.34–4.
M - slide ZW3c, EF: N.45–3.
N - slide ZW3b, EF: S.50.
O - slide ZW3a, EF: L.42–4.
P - slide ZW3b, EF: R.47.

Q–R - undetermined acritarchs.

Q - slide ZW3b, EF: U.43–2.
R - slide ZW3c, EF: G.49–1.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H
I
J
K
L
M
N
O
P
Q
50 µm
R

Fig. 8

Organic–walled microfossils of the Kosov Formation (Hirnantian, Ordovician), localities Levín (B–C, G–H, K, N) and Hlásná Třebáň (A, D–F, I–J, L–M, O).

A–E - poorly preserved ?*Leiosphaeridia* sp.
A - slide HlTr–01–01, EF: T.32–2.
B - slide Levín–02–01, EF: M.32.
C - slide Levín–02–02, EF O.59–4.
D - slide HlTr–01–01, EF: F.39–1.
E - slide HlTr–01–01, EF: Z.54–2.

F–G - fragments of pseudocelular cuticle.
F - slide HlTr–01–01, EF: T.55–2.
G - slide Levín–01, EF: P.53–3.

H - tubular fossil - slide Levín–02–02, EF: U.29–4.

I - paulinitid scolecodont - slide HlTr–01–01, EF: E.31–4.

J - undetermined scolecodont - slide HlTr–01–01, EF: H.38–1.

K - *Euconochitina* sp. - slide Levín–01, EF: E.25–4.

L - *Conochitina* sp. - slide HlTr–01–01, EF: Z.48–4.

M - *Cyathochitina* sp. - slide HlTr–01–02, EF: E.48–4.

N - ?*Spinachitina* sp. - slide Levín–02–02, EF: R.29–1.

O - *Conochitina* sp. - slide HlTr–01–01, EF: X.43–4.


A
B
C
D
E
F
G
50 µm
H
I
J
K
L
M
N
O

Fig. 9

Chitinozoans and scolecodonts of the Daleje Shale (Emsian, Devonian), locality Pod Dračí skálou.

A - ?*Sphaerochitina* sp. - slide DB–DS2a, EF: M.48–3.

B - *Ancyrochitina* sp. - slide DB–DS2c, EF: P.39–4.

C - ?*Ancyrochitina* sp. - slide DB-DS2c, EF: X.37–2.

D - *Ancyrochitina* sp. - slide DB-DS2c, EF: F.27–2.

E - *Angochitina* sp. - slide DB-DS2c, EF: R.46–1.

F - ?*Ancyrochitina* sp. - slide DB-DS2c, EF: E.29–1.

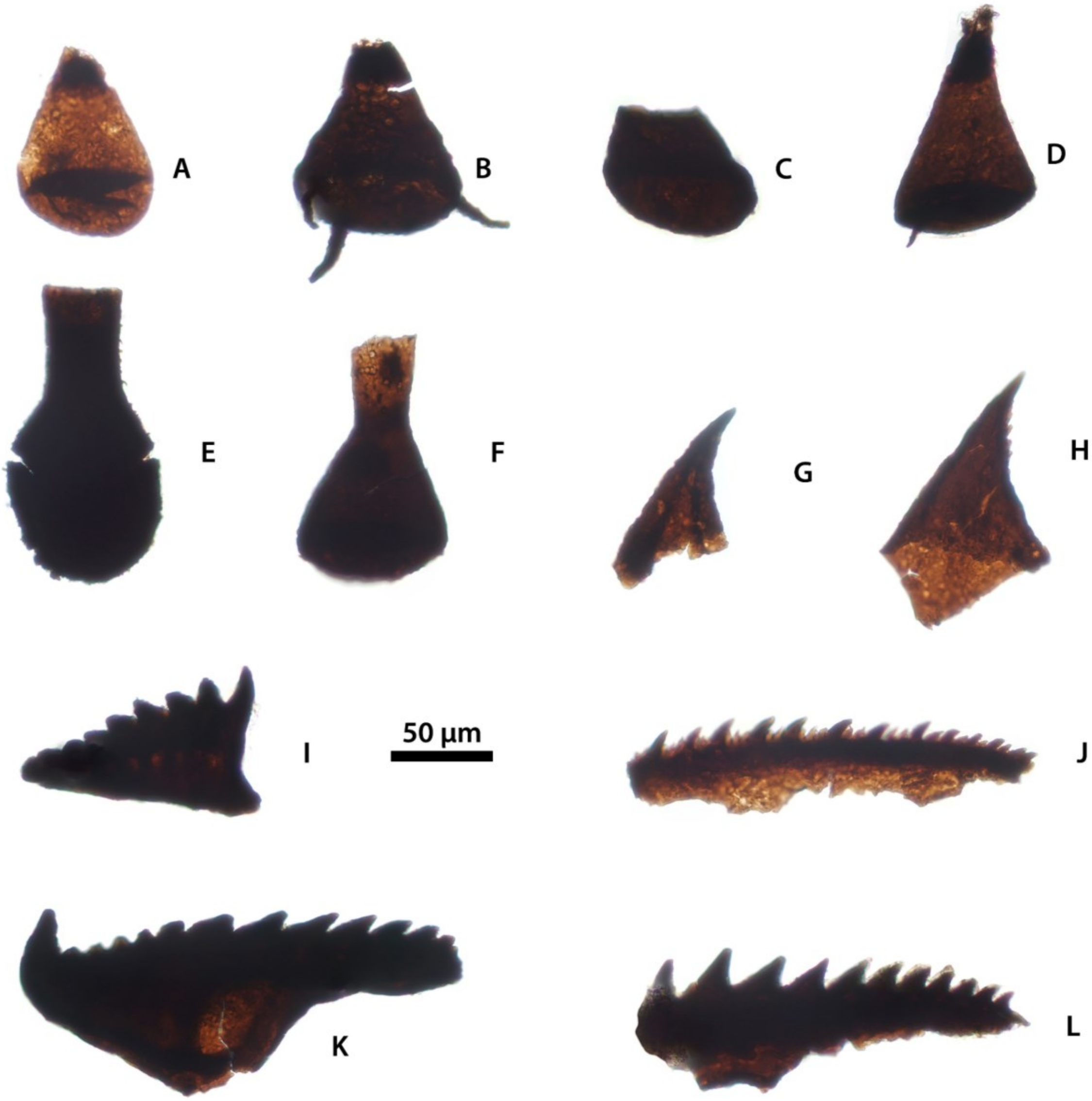
G–H - undetermined scolecodont fragments
G - slide DB-DS2c, EF: W.28–4.
H - slide DB-DS2c, EF: H.36.

I - polychaetaspid scolecodont, possibly ?*Oenonites* sp. - slide DB-DS2c, EF: W.40–2.

J - indeterminate scolecodont - slide DB-DS2c, EF: V.37–1.

K - paulinitid scolecodont - slide DB-DS2c, EF: W.28.

L - ?tetraprionid scolecodont - slide DB-DS2c, EF: Q.32–2.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50 µm
J
K
L

Fig. 10

Organic–walled microfossils of the Daleje Shale (Emsian, Devonian), locality Pod Dračí skálou.

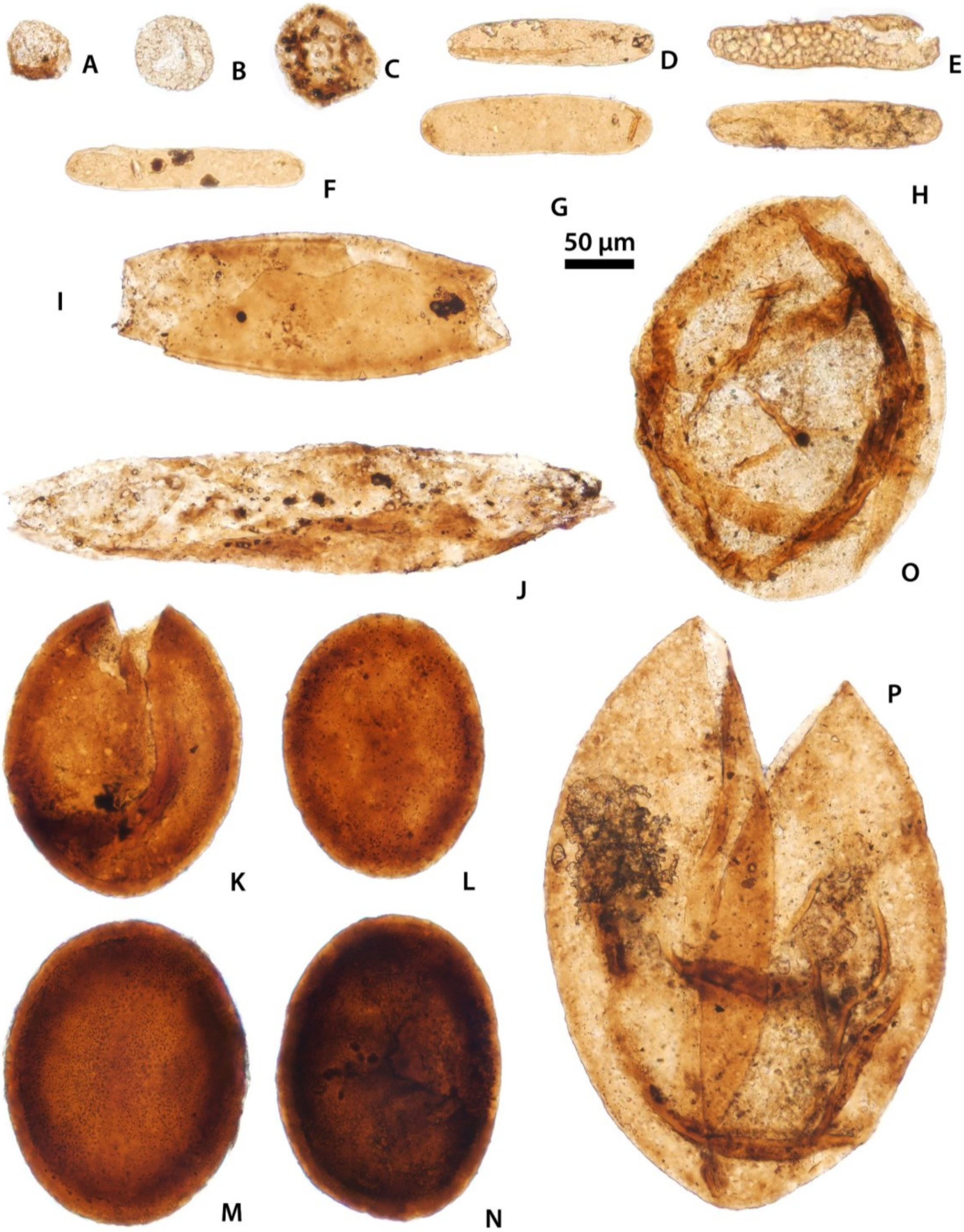
A–C - *Leiosphaeridia* sp.
A - slide DB–DS2c, EF: U.41–4.
B - slide DB–DS2c, EF: G.40–2.
C - slide DB–DS2c, EF: Q.31–4.

D–H - *Navifusa* sp.
D - slide DB–DS2b, EF: G.39–4.
E - slide DB–DS2b, EF: Q.43–2.
F - slide DB–DS2b, EF: J.47–2.
G - slide DB–DS2a, EF: T.43–3.
H - slide DB–DS2c, EF: Q.43–1.

I–J - ?*Navifusa* sp.
I - slide DB–DS2b, EF: H.35–4.
J - slide DB–DS2a, EF: H.36–3.

K–N - ?*Tasmanites* sp.
K - slide DB–DS2b, EF: K.42–3.
L - slide DB–DS2b, EF: Q.38.
M - slide DB–DS2c, EF: M.48–3.
N - slide DB–DS2b, EF: V.37–1.

O–P - *Leiosphaeridia* sp.
O - slide DB–DS2b, EF: L.32–2.
P - slide DB–DS2c, EF: D.32–3.


A
B
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D
E
F
G
H
50 µm
I
J
O
K
L
P
M
N

Fig. 11

Fossils of the Roblín Member (Givetian, Devonian), localities Hlubočepy (A–R) and Hostim (S–T).

A–C - ?*Grandispora* spp.
A - slide SS–ŽZ1, EF: L.32–3.
B - slide SS–ŽZ2d, EF: V.40–1.
C - slide SS–ŽZ2d, EF: U.39–4.

D - cryptospore - SS–ŽZ2d, EF: V.32–4.

E–G - undetermined spores.
E - slide SS–ŽZ2d, EF: T.31–3.
F - slide SS–ŽZ2c, EF: C.39–4.
G - slide SS–ŽZ2d, EF: W. 32–4.

H - cryptospore - slide SS–ŽZ2d, EF: U.27–3.

I–J - undetermined spores.
I - slide SS–ŽZ2c, EF: R.23–4.
J - slide SS–ŽZ2d, EF: P.45–4.

K–N - ?*Leiosphaeridia* sp.
K - slide HLUB–A1–02, EF: L.46–1.
L - slide HLUB–A1–01, EF: V.35–4.
M - slide HLUB–A1–04, EF: F.51–4.
N - slide HLUB–A1–03, EF: E.48–2.

O - fusiform acritarch - slide SS–ŽZ2c, EF: N.41–2.

P–R - ?*Leiosphaeridia* sp.
P - slide HLUB–A1–04, EF: W.42–1.
Q - slide HLUB–A1–04, EF: E.48–2.
R - slide HLUB–A1–03, EF: G.37–2.

S - plant fragment - slide SS–HZ1a, EF: M.54–3.

T - ?*Leiosphaeridia* sp. - slide SS–HZ1a, EF: V.33–1.

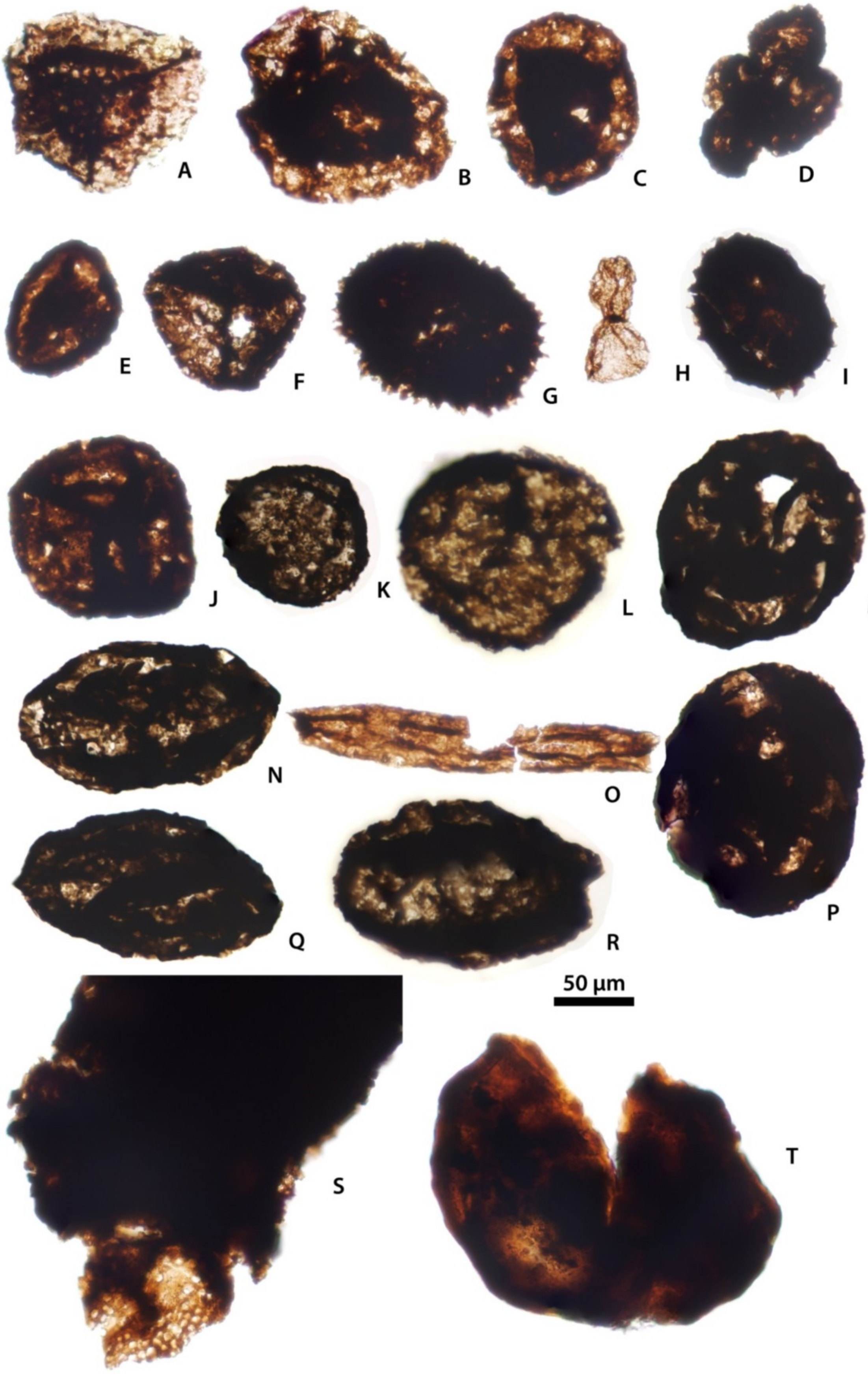

A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P
Q
R
50 µm
S
T

fig. 1–2

Fossils of the Roblín Member (Givetian, Devonian), locality Hlubočepy.

A–F - Undetermined fragments of scolecodonts.
A - slide HLUB–A1–02, EF: W.42–1.
B - slide HLUB–A1–03, EF: L.46–1.
C - slide SS–ŽZ2d, EF: U.39–4.
D - slide HLUB–A1–04, EF: W.25–4.
E - slide SS–ŽZ1a, EF: Y.42–1.
F - slide SS–ŽZ1a, EF: G.44–2.

G - Undetermined chitinozoan - slide SS–ŽZ2d, EF: P.34–1.

H – K - putative metazoan remains
H - slide SS–ŽZ2d, EF: N.42–3.
I - slide SS-ŽZ2d, EF: H.38–2.
J - slide SS–ŽZ2b, EF: W.49–1.
K - slide HLUB–A1–01, EF: N.37–4


A
B
C
D
E
F
G
H
I
J
K
50 µm

fig. 13

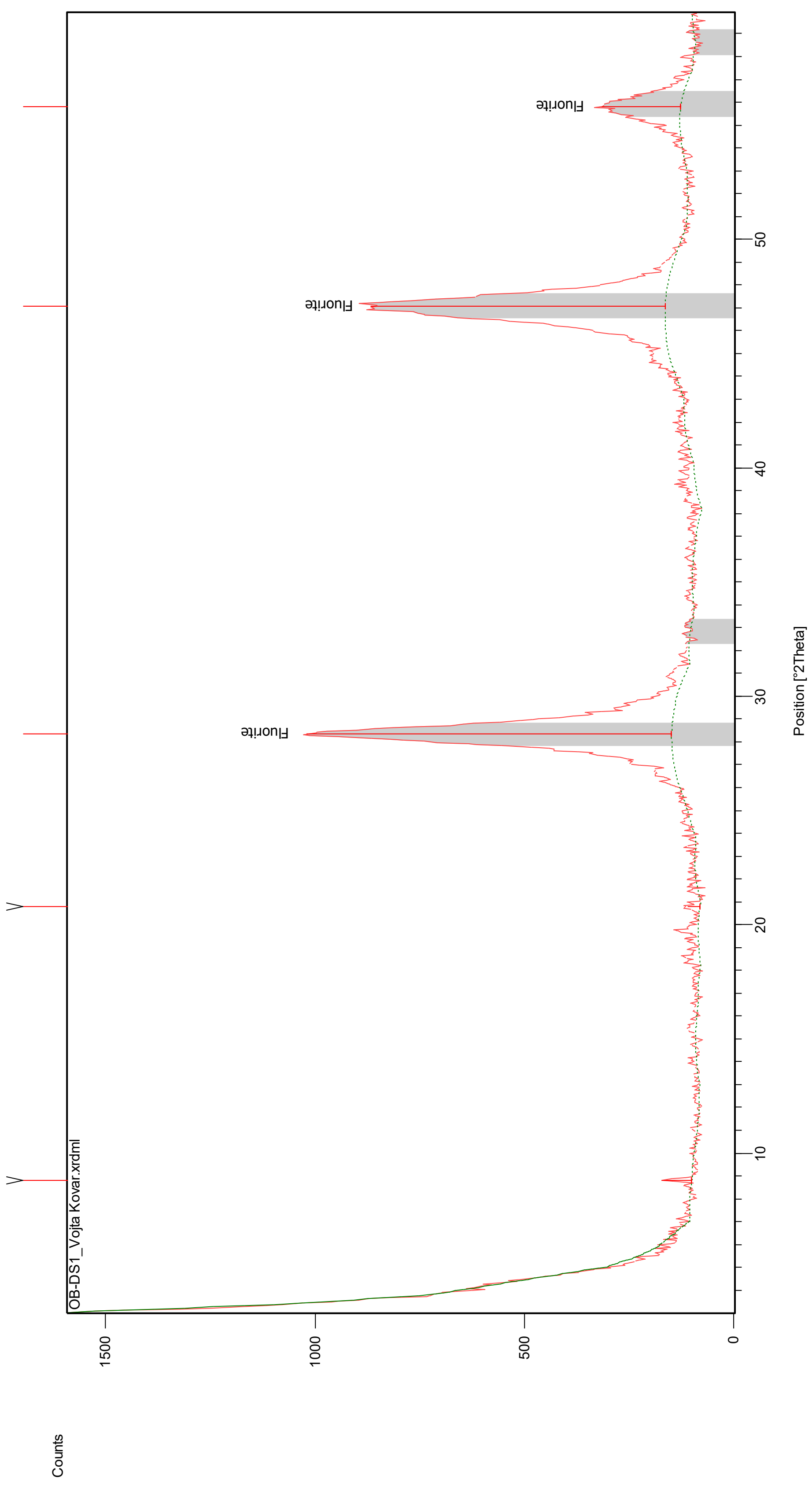
Fluoritised tentaculites from the Daleje Shale (Eifelian, Devonian), locality Pod Dračí skálou. - Scale bar represents 500 µm.
A - stub DB–DS01.
B - stub DB–DS01–02.
C - stub DB–DS01–02.
D - stub DB–DS01–02.
E - stub DB–DS01–02.
F - slide SS-ŽZ1bI, EF: T.43–2.
G - slide SS-ŽZ1bI, EF: Q.41–1.
H - slide SS-ŽZ1bI, EF: U.46–2.

Fluoritised fragment of tentaculite from the Roblín Member (Givetian, Devonian), locality Hlubočepy. - Scale bar represents 100 µm.
I - slide SS-ŽZ2d, EF: V.29–2.


A
B
C
D
E
F
I
G
H

fig. 14

Results of the X–Ray diffraction of fluoritised tentaculite from the Daleje Shale.



OB-DS1_Vojta Kovar.xrdml
Counts
1500
1000
500
0
10
20
30
40
50
Position [°2Theta]
Fluorite
Fluorite
Fluorite

Appendix 1 – List of Recovered Fossil Groups and Taxa

Cambrian

Paseky Shale Member

<u>Remains of metazoan affinity</u>
?*Ceratophyton* sp.
?*Protohertzina* sp.
Bilateralian mouthparts.
<u>Remains of probable algal affinity – acritarchs *s.l.*</u>
Leiosphaeridia sp.
<u>Remains of probable algal affinity – non–acritarchs</u>
Botuobia sp.
Polytrichoides sp.
Siphonophycus spp.
<u>Remains of probable plant affinity</u>
Undetermined cryptospores

Jince Formation

<u>Remains of metazoan affinity</u>
Wiwaxia sp.
<u>Remains of probable algal affinity – acritarchs *s.l.*</u>
Adara sp.
?*Annulum* sp.
Cymatiosphaera sp.
Eliasum sp.
Leiosphaeridia spp.
Skiagia sp.
?*Stictosphaeridium* sp.
Timofeevia sp.
<u>Remains of probable algal affinity - non-acritarchs</u>
Undetermined filaments
<u>Remains of probable plant affinity</u>
Undetermined cryptospores

Ordovician

Letná Formation

<u>Remains of metazoan affinity – scolecodonts</u>
Undetermined scolecodonts
<u>Remains of probable metazoan affinity – chitinozoa</u>
?*Belonechitina* sp.
Conochitina sp.
Cyathochitina sp.
Desmochitina sp.
Euconochitina sp.
Linochitina sp.
<u>Remains of probable metazoan affinity</u>
Undetermined cuticles

Remains of probable algal affinity – acritarchs *s.l.*
Ordovicidium sp.
?*Leiosphaeridia* sp.
Veryhachium sp.

Kosov Formation
Remains of metazoan affinity – scolecodonts
Paulinitidae
Undetermined scolecodonts
Remains of probable metazoan affinity – chitinozoa
Conochitina sp.
Cyathochitina sp.
Euconochitina sp.
?*Spinachitina* sp.
Remains of probable algal affinity – acritarchs *s.l.*
?*Leiosphaeridia* sp.
Remains of probable algal affinity – non–acritarchs
Pseudocelular cuticles
Remains of probable plant affinity
Undetermined tubular fossil

Devonian
Daleje Shale Member

Remains of metazoan affinity – scolecodonts
Paulinitidae
Polychaetaspidae (?*Oenonites* sp.)
Remains of metazoan affinity
Undetermined tentaculitoids
Undetermined trilobites
Undetermined brachiopods
Remains of probable metazoan affinity – chitinozoa
Ancyrochitina sp.
Angochitina sp.
?*Sphaerochitina* sp.
Remains of probable algal affinity – acritarchs *s.l.*
?*Leiosphaeridia* sp.
Navifusa sp.
Tasmanites sp.

Srbsko Formation
Remains of metazoan affinity – scolecodonts
Undetermined scolecodonts
Remains of metazoan affinity – tentaculitoids
Undetermined tentaculitoids

Remains of probable metazoan affinity – chitinozoa
Undetermined chitinozoa
Remains of probable metazoan affinity
?fragments of arthropod cuticles
Undetermined fragments
Remains of probable algal affinity – acritarchs *s.l.*
?*Leiosphaeridia* spp.
Undetermined fusiform acritarch
Remains of plant affinity
?*Grandispora* sp.
Undetermined cryptospores
Undetermined spores
Undetermined plant debris